High School Content Expectations

SCIENCE

- Earth and Space
- Biology
- Physics
- Chemistry

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Science Work Group

Planned Academic Review

Andy Anderson, Co-Chair
Michigan State University

Robert Poel, Co-Chair
Western Michigan University, (ret.)

Theron Blakeslee
Ingham ISD

Carol Clark
MI Dept. Labor & Economic Growth

Brian Coppola
University of Michigan

Mark Davids
Grosse Pointe South High School

Claudia Douglass
Central Michigan University

Kaz Fujita
Michigan State University

George Goff
Detroit King High School

Annis Hapkiewicz
Okemos High School, (ret.)

Marilyn Rands
Lawrence Technological University

Walter Rathkamp
Saginaw Valley State University

Kevin Richard
Michigan Department of Education

Judy Ruddock
Flint Public Schools, (ret.)

Sandra Rutherford
Eastern Michigan University

Michael Seymour
Hope College

Randy Showerman
MI Dept. Labor & Economic Growth

Betty Underwood
Michigan Department of Education

Planned Internal Review

Larry Calser
Genesee Math Science Center

Paul Drummond
Macomb ISD

Michael Gallagher
Oakland Schools

Shamarion Green
Flint Schools

Joseph Grigas
Lake Fenton High School

Cheryl Hach
Kalamazoo Math Science Center

Ardis Herrold
Grosse Pointe South High School

Michael Klein
Macomb ISD

Dave Peters
East Kentwood High School

Kevin Richard
Michigan Department of Education

Gary Waterson
Benzie Central High School

Project Coordinator

Susan Codere Kelly
Michigan Department of Education

Welcome to Michigan's High School Science Content Standards and Expectations

Why Develop Content Standards and Expectations for High School?

In 2004, the Michigan Department of Education embraced the challenge to initiate a "high school redesign" project. Since then, the national call to create more rigorous learning for high school students has become a major priority for state leaders across the country. The Cherry Commission Report highlighted several goals for Michigan including the development of high school content expectations that reflect both a rigorous and a relevant curricular focus. Dovetailing with this call to "curricular action" is Michigan's legislative change in high school assessment. The Michigan Merit Exam, based on rigorous high school learning standards, is to be full implemented by 2007.

The Michigan Department of Education's Office of School Improvement led the development of high school content expectations. A science academic review group of academicians chaired by nationally known scholars was commissioned to conduct a scholarly review and identify content standards and expectations. The Michigan Department of Education will conduct an extensive field review of the expectations by high school, university, and business and industry representatives.

The Michigan High School Science Content Expectations (Science HSCE) establish what every student is expected to know and be able to do by the end of high school and define the expectations for high school science credit in Earth and Space Science, Biology, Physics, and Chemistry.

An Overview

This is a first draft of Science Content Expectations for Michigan High Schools. It was developed by the Science Academic Review Work group. In developing these expectations, the group depended heavily on the *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2006).
In particular, the group adapted the structure of the NAEP framework (including Content Statements, Performance Expectations, and Boundaries). These expectations align closely with the NAEP framework, which is based on *Benchmarks for Science Literacy* (AAAS Project 2061, 1993) and the *National Science Education Standards* (National Research Council, 1996).

The academic review group carefully analyzed other documents, including the Michigan Curriculum Framework Science Benchmarks (2000 revision), the Standards for Success report *Understanding University Success*, ACT's *College Readiness Standards*, College Board's *AP Biology, AP Physics, AP Chemistry,* and *AP Environmental Science Course Descriptions*, ACT's *On Course for Success*, South Regional Education Board's *Getting Ready for College-Preparatory/Honors Science: What Middle Grades Students Need to Know and Be Able to Do,* and standards documents from other states.

Earth & Space Science	Biology	Physics	Chemistry
STANDARDS *(and number of Content Statements in each standard)*			
E1 Systems and Processes in the Environment (4) E2 The Solid Earth (4) E3 The Fluid Earth (4) E4 Earth in Space and Time (9) E5 Chemicals in the Environment (3)	B1 Organization and Development of Living Systems (6) B2 Interdependence of Living Systems and the Environment (4) B3 Genetics (6) B4 Evolution and Biodiversity (3)	P1 Forms of Energy and Energy Transformations (24) P2 Motion of Objects (3) P3 Forces and Motion (10)	C1 Forms of Energy (5) C2 Energy Transfer and Conservation (5) C2 Properties of Matter (10) C3 Changes in Matter (8)

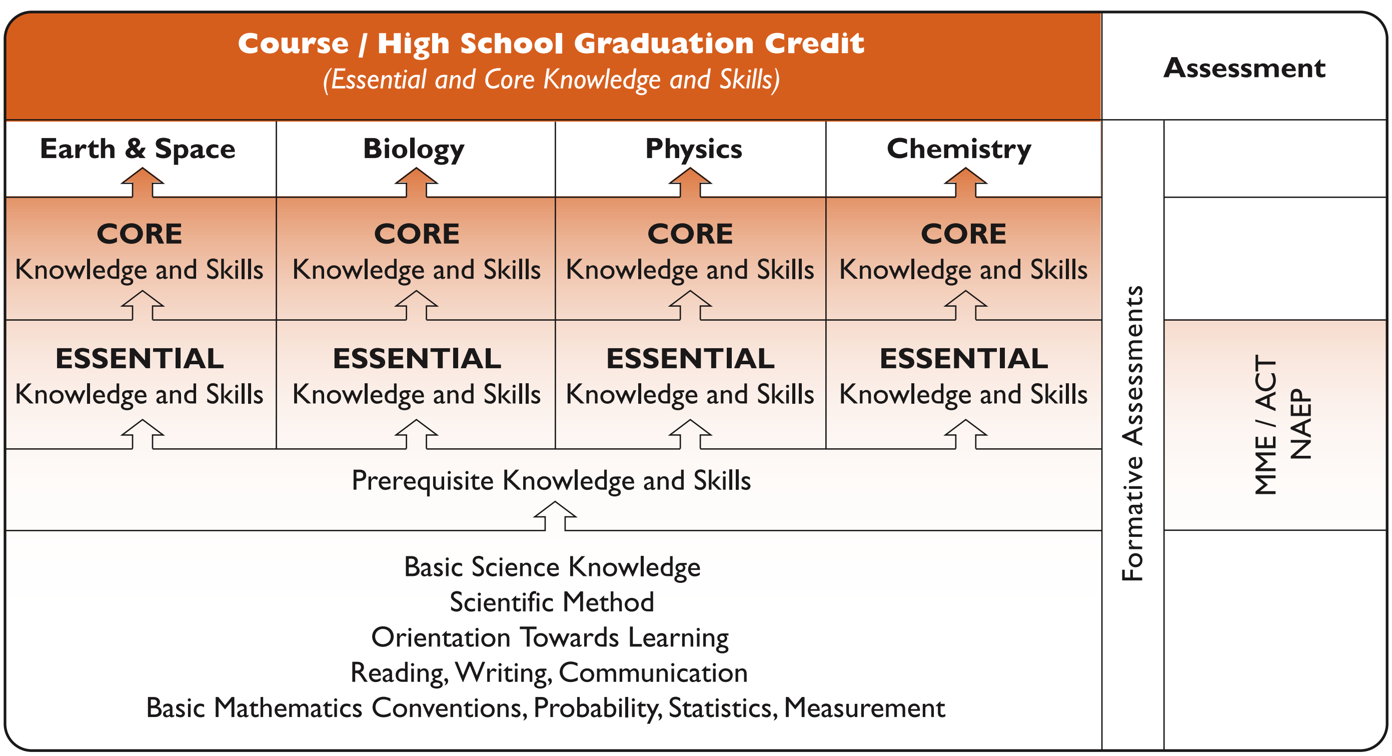
Useful and Connected Knowledge for All Students

This draft defines expectations for Michigan High School graduates, organized by discipline: Earth and Space Science, Biology, Physics, and Chemistry. It defines ***useful*** and ***connected knowledge*** at three levels:

- **Prerequisite knowledge**
  Useful and connected knowledge that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed in the Essential category. Prerequisite content statements and expectations will be included in the middle school science expectations when they are written.
- **Essential knowledge**
  Useful and connected knowledge for all high school graduates, regardless of what courses they take in high school. In general, essential knowledge consists of content and skills that all students need to know and be able to do. Essential content and expectations will be assessable on large-scale assessments (MME/ACT, NAEP).
- **Core knowledge**
  Useful and connected knowledge for students who have completed a discipline-specific course. In general, core knowledge includes content and expectations that students need to be prepared for more advanced study in that discipline.

Useful and connected knowledge is contrasted with ***procedural display***—learning to manipulate words and symbols without fully understanding their meaning. When expectations are excessive, procedural display is the kind of learning that takes place. Teachers and students "cover the content" instead of striving for useful and connected knowledge.

Credit for high school Earth and Space Science, Biology, Physics, and Chemistry will be defined as meeting both essential and core subject area content expectations.



High School Science Overview

Preparing Students for Successful Post-Secondary Engagement

Students who have useful and connected knowledge should be able to apply knowledge in new situations; to solve problems by generating new ideas; to make connections among what they read and hear in class, the world around them, and the future; and through their work, to develop leadership qualities while still in high school. In particular, high school graduates with useful and connected knowledge are able to engage in four key practices of science literacy.

Successful Post-Secondary Engagement

Practices of Science Literacy

Communicate accurately and effectively...

Identifying Science Principles

- Describe, measure, or classify observations
- State or recognize correct science principles
- Demonstrate relationships among closely related science principles
- Demonstrate relationships among different representations of principles

Using Science Principles

- Explain observations of phenomena
- Predict observations of phenomena
- Suggest examples of observations that illustrate a science principle
- Propose, analyze, and evaluate alternative explanations or predictions

Scientific Inquiry

- Generate new questions that can be investigated empirically.
- Design and critique aspects of scientific investigations.
- Conduct scientific investigations using appropriate tools and techniques, recognizing limitations.
- Identify patterns in data and/or relate patterns in data to theoretical models.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions.
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable.
- Gather data and organize the results in graphs, tables, and/or charts.

Reflection and Technology

- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Identify and critique arguments based on scientific evidence.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Propose or critique solutions to problems given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Apply scientific models or patterns in data to technological design decisions.

State/National Landscape

- Expert perspective
- Education reform environment
- Research-based practices
- Work force requirements

State/Federal Expectations

- No Child Left Behind (NCLB)
- National Governors' Association (NGA)
- Legislation/Policy

Michigan High School Science Content Standards and Expectations

Earth and Space Science

Biology

Physics

Chemistry

Models for District Alignment / Mapping

- District curriculum documents
- Documents from other districts/states
- Backmapping to standards and expectations

Other MI Documents/Programs

- State Standards – teaching and learning, content (all areas), assessment
- Grade Level Content Expectations
- State Assessments
- Career/Technical Education
  Department of Labor and Economic Growth

K-8 Educational Experience

Content Knowledge

- English Language Arts
- Mathematics
- Science
- Social Studies
- Other

Learning Processes

- Strategies & Skills
- Reasoning
- Analytical Thinking
- Constructing New Meaning
- Communication

This chart includes talking points for the professional development model.

Practices of Science Literacy

- **Identifying**
  Indentifying performances generally have to do with stating models, theories, and patterns inside the triangle in Figure 1.
- **Using**
  Using performances generally have to do with the downward arrow in Figure 1—using scientific models and patterns to explain or describe specific observations.
- **Inquiry**
  Inquiry performances generally have to do with the upward arrow in Figure 1—finding and explaining patterns in data.[1]
- **Reflecting and Technology**
  Reflecting and *Technology* performances generally have to do with the figure as a whole (reflecting) or the downward arrow (technology as the application of models and theories to practical problems.

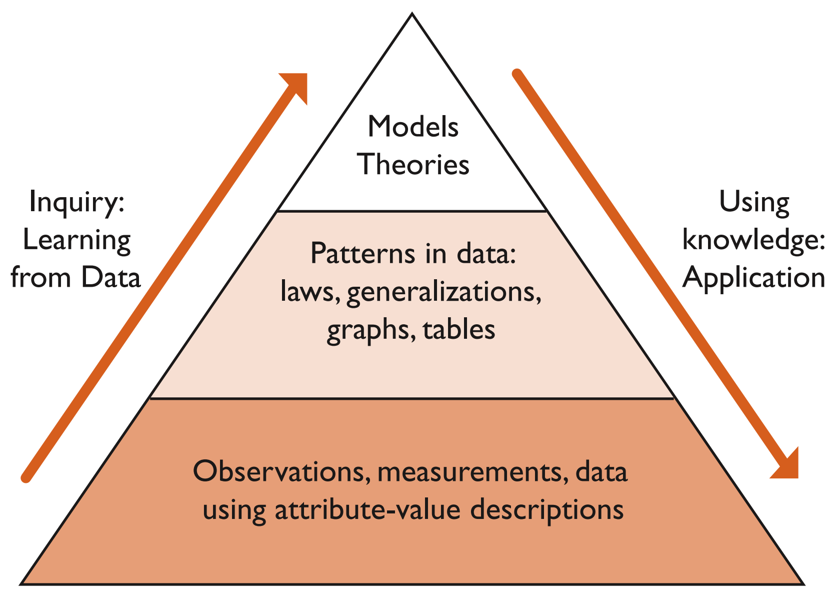


Figure 1: Knowledge and practices of model-based reasoning

Identifying Science Principles

This category focuses on students' ability to recall, define, relate, and represent basic science principles. The content statements themselves are often closely related to one another conceptually. Moreover, the science principles included in the content statements can be represented in a variety of forms, such as words, pictures, graphs, tables, formulas, and diagrams (AAAS, 1993; NRC, 1996). Identifying practices include describing, measuring, or classifying observations; stating or recognizing principles included in the content statements; connecting closely related content statements; and relating different representations of science knowledge.

Identifying Science Principles comprises the following general types of practices:

- Describe, measure, or classify observations (e.g., describe the position and motion of objects, measure temperature, classify relationships between organisms as being predator/prey, parasite/host, producer/consumer)
- State or recognize correct science principles (e.g., "mass is conserved when substances undergo changes of state;" "all organisms are composed of cells;" "the atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor")
- Demonstrate relationships among closely related science principles (e.g., statements of Newton's three laws of motion, energy transfer and the water cycle)
- Demonstrate relationships among different representations of principles (e.g., verbal, symbolic, diagrammatic) and data patterns (e.g., tables, equations, graphs)

Identifying Science Principles is integral to all of the other science practices.

Using Science Principles

Scientific knowledge is useful for making sense of the natural world. Both scientists and informed citizens can use patterns in observations and theoretical models to predict and explain observations that they make now or that they will make in the future.

Using Science Principles comprises the following general types of performance expectations:

- Explain observations of phenomena (using science principles from the content statements)
- Predict observations of phenomena (using science principles from the content statements, including quantitative predictions based on science principles that specify quantitative relationships among variables)
- Suggest examples of observations that illustrate a science principle (e.g., identify examples where the net force on an object is zero; provide examples of observations explained by the movement of tectonic plates; given partial DNA sequences of organisms, identify likely sequences of close relatives)
- Propose, analyze, and evaluate alternative explanations or predictions

The first two categories—***Identifying Science Principles*** and ***Using Science Principles***—both require students to correctly state or recognize the science principles contained in the content statements. A difference between the categories is that Using Science Principles focuses on what makes science knowledge valuable—that is, its usefulness in making accurate predictions about phenomena and in explaining observations of the natural world in coherent ways (i.e., "knowing why"). Distinguishing between these two categories draws attention to differences in depth and richness of individuals' knowledge of the content statements. Assuming a continuum from "just knowing the facts" to "using science principles," there is considerable overlap at the boundaries. The line between the Identifying and Using categories is not distinct.

Scientific Inquiry

Scientifically literate graduates make observations about the natural world, identify patterns in data, and propose explanations to account for the patterns. Scientific inquiry involves the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses to explain patterns in data. Scientific inquiry is a complex and time-intensive process that is iterative rather than linear. Habits of mind—curiosity, openness to new ideas, informed skepticism—are part of scientific inquiry. This includes the ability to read or listen critically to assertions in the media, deciding what evidence to pay attention to and what to dismiss, and distinguishing careful arguments from shoddy ones. Thus, Scientific Inquiry depends on the practices described above—Identifying Science Principles and Using Science Principles.

Scientific Inquiry comprises the following general types of performance expectations:

- Generate new questions that can be investigated in the laboratory or field.
- Design and critique aspects of scientific investigations (e.g., involvement of control groups, adequacy of sample)
- Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision)
- Identify patterns in data and/or relate patterns in data to theoretical models
- Describe a reason for a given conclusion using evidence from an investigation.
- Explain how scientific evidence supports or refutes claims or explanations of phenomena.
- Predict what would happen if the variables, methods, or timing of an investigation were changed.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions (e.g., check to see that the premises of the argument are explicit, notice when the conclusions do not follow logically from the evidence given)
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts.

Scientific inquiry is more complex than simply making, summarizing, and explaining observations, and it is more flexible than the rigid set of steps often referred to as the "scientific method." The *National Standards* makes it clear that inquiry goes beyond "science as a process" to include an understanding of the nature of science (p. 105). Further:

It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations (p. 171).

When students engage in Scientific Inquiry, they are drawing on their understanding about the nature of science, including the following ideas (see Benchmarks for Science Literacy):

- Arguments are flawed when fact and opinion are intermingled or the conclusions do not follow logically from the evidence given
- A single example can never support the inference that something is always true, but sometimes a single example can support the inference that something is not always true
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables
- The way in which a sample is drawn affects how well it represents the population of interest. The larger the sample, the smaller the error in inference to the population. But, large samples do not necessarily guarantee representation, especially in the absence of random sampling

Students can demonstrate their abilities to engage in Scientific Inquiry in two ways: students can *do* the practices specified above, and students can *critique examples* of scientific inquiry. In *doing*, practices can include analyzing data tables and deciding which conclusions are consistent with the data. Other practices involve hands-on performance and/or interactive computer tasks—for example, where students collect data and present their results or where students specify experimental conditions on computer simulations and observe the outcomes. As to *critiquing*, students can identify flaws in a poorly designed investigation or suggest changes in the design in order to produce more reliable data. Students should also be able to critique print or electronic media—for example, items may ask students to suggest alternative interpretations of data described in a newspaper article. For more on item formats, please see Chapter Four.

Reflection and Technological Design

Scientifically literate people recognize the strengths and limitations of scientific knowledge, which will provide the perspective they need to use the information to solve real-world problems. Students must learn to decide who and what sources of information they can trust. They need to learn to critique and justify their own ideas and the ideas of others. Since knowledge comes from many sources, students need to appreciate the historical origins of modern science and the multitude of connections between science and other disciplines. Students need to understand how science and technology support one another and the political, economic, and environmental consequences of scientific and technological progress. Finally, it is important that the ideas and contributions of men and women from all cultures be recognized as having played a significant role in scientific communities.

In both the *National Standards* and *Benchmarks*, the term "technological design" refers to the process that underlies the development of all technologies, from paperclips to space stations. Technological Design describes the systematic process of applying science knowledge and skills to solve problems in a real-world context. The reason for including technological design in the science curriculum is clearly stated in the *National Standards*: "Although these are science education standards, the relationship between science and technology is so close that any presentation of science without developing an understanding of technology would portray an inaccurate picture of science" (p. 190).

Reflection and Technological Design include the following general types of practices, all of which entail students using science knowledge to:

- Critique whether questions can be answered through scientific investigations.
- Identify and critique arguments based on scientific evidence.
- Compare the effectiveness of different graphics and tables to describe patterns, explanations, conclusions, and implications found in investigations.
- Explain why results from a single investigation or demonstration are not conclusive.
- Explain why a claim or a conclusion is flawed (e.g. limited data, lack of controls, weak logic).
- Propose or critique solutions to problems, given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Apply science principles or data to anticipate effects of technological design decisions.
- Explain the social, economic, and environmental advantages and risks of new technology.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Discuss topics in groups by making clear presentations, restating or summarizing what others have said, asking for clarification or elaboration, taking alternative perspectives, and defending a position.

Organization of the Expectations

The Science Expectations are organized into Disciplines, Standards, Content Statements, and specific Performance Expectations.

Disciplines

Earth and Space Science, Biology, Physics and Chemistry.

Organization of Each Standard

Each standard includes four parts, described below.

- A standard statement that describes what students who have mastered that standard will be able to do.
- Content statements that describe Prerequisite, Essential, and Core science content understanding for that standard.
- Performance expectations that describe Prerequisite, Essential, and Core performances for that standard.
- Boundary statements that clarify the standards to set limits to expected performances.

Standard Statement

The Standard Statement describes how students who meet that standard will engage in Identifying, Using, Inquiry, or Reflection for that topic.

Content Statements

Content statements describe the Prerequisite, Essential, and Core *knowledge* associated with the standard. This draft identifies five levels of expectations:

1. ***Prerequisite science content*** that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed with Essential content and printed in the left-hand column of the expectations documents.
2. ***Essential science content*** that all high school graduates should master. Essential content and expectations are organized by topic (e.g., E4.2 Earth in Space) and printed in the left-hand column of the expectations documents.
3. ***Core science content*** that high school graduates need for more advanced study in the discipline and for some kinds of work. Core content and expectations are organized by topic (e.g., E4.3x Stars; note that "x" designates a core topic) and printed in the right-hand column of the expectations document.
4. ***Basic mathematics skills.*** These will be included in an Appendix at the end of the document.
5. ***Basic English language arts skills.*** These will be included in an Appendix at the end of the document.

Performance Expectations

Performance expectations are derived from the intersection of content statements and practices—if the content statements from the Earth and Space Sciences, Biology, Physics, and Chemistry are the columns of a table and the practices (Identifying Science Principles, Using Science Principles, Using Scientific Inquiry, Reflection and Technological Design) are the rows, the cells of the table are inhabited by performance expectations.

Performance expectations are written with particular verbs indicating the desired performance expected of the student. The action verbs associated with each practice are not firmly fixed. The use of any action verb must be contextualized. For example, when the "conduct scientific investigations" is crossed with a states-of-matter content statement, this can generate a performance expectation that employs a different action verb, "heats as a way to evaporate liquids."

Boundaries

Boundaries elaborate the Performance Expectations. The boundaries are intended as "notes to curriculum and assessment developers," not as comprehensive descriptions of the full range of science content to be included in the high school science curriculum. In the boundary statements, the terms "such as," "including," "e.g.," and "etc." are used to denote suggestions. The boundaries do not stand alone and should be considered in conjunction with the relevant content statements and narrative introductions for each of the disciplines—Earth and Space Science, Biology, Physics, and Chemistry. Some content statements are very detailed and require less specification of boundaries. Although the boundaries relevant to a given subtopic may focus more heavily on some content statements than others, this is not intended to denote a sense of content priority.

Michigan High School Science

EARTH & SPACE

Prerequisite, Essential, and Core Content Statements and Expectations

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EARTH AND SPACE SCIENCE (E)

In recent years, the study of Earth has undergone profound changes. It has shifted from surface geology and the recovery of economic resources toward global change and Earth systems. Concurrently, research methods have changed from human observations and mapping to remote sensing and computer modeling. The advent of technology has made it possible to conduct more integrated and interdisciplinary research and view the Earth as a single dynamic entity composed of four interacting systems. The Earth System is usually subdivided into the geosphere (solid Earth), the hydrosphere (the liquid part of the planet), the atmosphere (the gaseous part of the planet), and the biosphere (the living part of the planet). These four parts do not exist in isolation, but are interconnected by complex cycles. Alterations to one part of the Earth system result in effects on another part of the system. The study of the individual components and their interactions are necessary to completely understand the complex dynamics of our planet.

There has also been a shift in goals, as advances in theory have made it possible to more accurately predict changes (especially in weather and climate), to provide life-saving warnings of floods, hurricanes, and volcanic eruptions, and to understand how human activities influence air and water quality, ecosystems, and climate across the globe. We are also better prepared to understand the processes that occur within and between each of the Earth systems.

Recent research in the Earth Sciences has focused on:

1. climate variability and change
2. impact of chemicals on ecosystems
3. water and energy cycles
4. atmospheric processes
5. earth surface and internal processes.

As national education standards have moved to mirror these foci, students must explore the methods and tools for studying Earth systems. In addition, public awareness and education is critical in mitigating the effects of natural hazards as economic and population growth expand in areas susceptible to the effects of nature (e.g., Florida, Texas, California). The impact of such events as hurricane Katrina and the Sumatra tsunami demonstrate the significant impacts of the Earth on society. Some of the decisions students will need to consider include, where to live, where to store waste, and where to develop.

The Earth System, however, is generally too complex for students to view as whole, thus it is best to look at each of the components separately. It is imperative, however, that students inquire about and understand the interconnections between Earth systems and distinguish between systems at "micro" and "macro" levels. In light of this, many content statements in this document cross standard boundaries and are interconnected.

Unlike many other disciplines, direct experimentation is difficult in many aspects of the Earth Sciences. Even direct observations can be difficult and scientists must depend on the formulation of models both to describe and determine the implications of various factors. Many aspects of the Earth Sciences also occur over very long time frames ("deep time") that are studied more like a murder mystery with inferences from indirect data; such concepts are often difficult for students to comprehend.

On the other hand, the tools available to both scientists and students for learning about Earth and space have changed as well. Communication and visualization tools, such as the internet and data bases, have made it possible for Earth Science students to have direct access to the raw data and models used by scientists. Other web-based programs allow students to view and process satellite images of Earth, to direct a camera on board the Space Shuttle, and to access professional telescopes around the world to carry out science projects.

The five Earth and Space Science standards focus on:

1. the physical and material properties and processes of the environment in which we live
2. the solid earth and its hazards
3. the fluid earth and its hazards
4. the history of the Earth and the universe, and
5. the movement of chemicals through Earth Systems.

The standards begin with an overview of Earth systems and cycles that interconnect the individual subsystems within it. This is followed by an examination of the major components of the Earth system that are covered in Earth Science courses, focusing on the solid Earth (global tectonics) and fluid Earth (climate and weather). The next standard covers the position of the Earth in the universe and its evolution over time, including the near future. Finally, there is a return to the interconnections of the Earth system by examining chemicals as they move through the Earth and human impacts on these chemical cycles.

The interdisciplinary nature of the Earth Sciences makes it difficult to rigidly separate and sequence subject matter. Many topics can fit equally well in many different places. This document represents one organizational structure.

Outline of Earth and Space Science Expectations

Standard E1: Systems and Processes in the Environment

E1.1 Rocks
E1.2 Water
E1.3 Landforms and Soils (Middle School)
E1.4 Earth Systems Overview

Standard E2: The Solid Earth

E2.1 Structure of the Earth
E2.2 Plate Tectonics
E2.3x Plate Evolution
E2.4 Earthquakes and Volcanoes

Standard E3: The Fluid Earth

E3.1 Oceans
E3.2 Weather and the Atmosphere (Middle School)
E3.2x Global Circulation and Climate
E3.3 Severe Weather
E3.3x Mesometeorology
E3.4 Glaciers

Standard E4: Earth in Space and Time

E4.1 Sky Observations (Middle School)
E4.2 The Earth in Space
E4.3x Stars
E4.4x Magnetosphere
E4.5x Evidence for the Nature of the Universe
E4.6x Planetary Geology
E4.7 Earth History and Geologic Time
E4.8x The Early Earth
E4.9 Climate Change

Standard E5: Chemicals in the Environment

E5.1 Geochemical Cycles
E5.2 Energy Resources
E5.3 Human Effects on Earth Systems

Standard E1: Systems and Processes in the Environment

Standard Statement

Students will describe the interactions within and between Earth systems. Students will explain how both fluids (water cycle) and solids (rock cycle) move within Earth systems and how these movements form and change their environment. They will describe the relationship between physical process and human activities and use this understanding to make wise decisions about land use.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E1.1: Rocks –** Igneous, metamorphic, and sedimentary rocks are composed of minerals and are constantly forming and changing through various processes. As they do so, chemicals move through the Earth system. They are indicators of geologic and environmental conditions that existed in the past. ***Identifying and Using Performance Expectations*** **E1.p1** Identify common minerals by their properties. (***middle school prerequisite***) **E1.1A** Identify common igneous, metamorphic and sedimentary rocks and describe the processes that change one kind of rock to another. **E1.1B** Explain the relationship between the rock cycle and the plate tectonics theory. **Instruments, Measurement, and Representations** **Technical Vocabulary** Names, composition, and identification of common sedimentary, igneous, and metamorphic rocks. Common terms for processes in the rock cycle. **Clarifications** Focus on the rock cycle and rock forming processes and how the rock cycle is a part of plate tectonic and geochemical cycles.	***Content Statement*** **E1.1x Advanced Rock Cycle** – Rocks show evidence of changes over time. These include changes in, or exposure to, pressure and temperature, exposure to the surface, and transport. Many of these processes are controlled by plate tectonics and climate. ***Identifying and Using Performance Expectations*** **E1.1c** Explain how and why the size of rock fragments in a sedimentary rock might differ depending on whether it formed in the Arctic or the tropics. **E1.1d** Explain how the chemistry of rocks is affected at various stages of the rock cycle. **Instruments, Measurements, and Representations** **Technical Vocabulary** Chemical composition of important rock forming minerals such as quartz, feldspar, mica, hornblende, and pyroxene Models or animations to show how rocks weather in different environments such as the desert or tropics Common terms for the rock cycle **Clarifications** Focus on the chemistry of common rock forming minerals and how they change depending on the climate of a given area.
Content Statement **E1.2 Water** – Water circulates through the crust and atmosphere, and in oceans, rivers, glaciers and ice caps and connects all of the Earth systems. Groundwater is a significant reservoir and source of freshwater on Earth. The recharge and movement of groundwater depends on porosity, permeability, and the shape of the water table. The movement of ground water occurs over a long period time. Groundwater and surface water are often interconnected. ***Identifying and Using Performance Expectations***	***Content Statement*** **E1.2x Water and the Earth –** Water has unique properties that make it essential for both chemical reactions and the development of life. ***Identifying and Using Performance Expectations***

E1.2A Compare and contrast surface water systems and ground water systems. **E1.2B** Identify and describe your local watershed within the Great Lakes Basin using maps, including drainage basins, divides, reservoirs, tributaries, and surface run-off **E1.2C** Explain how heat is transferred through Earth Systems when water changes states. **Instruments, Measurement, and Representations** Know about instruments used to measure the flow of water Diagrams showing water cycle and role of heat stored in ocean as well as role of other Earth systems Charts of data to calculate the precipitation and vapor pressures (relative humidity) Data of thermal properties of water including heat capacity and latent heat as related to phase changes. **Technical Vocabulary** permeability, porosity, aquifer, water table, reservoirs, sedimentary transport Common terms such as evaporation, condensation, absorption, percolation, infiltration, surface runoff, and groundwater **Clarifications** Focus on cyclic nature of water and how it moves across boundaries and through Earth systems	**E1.2d** Describe how the density of pure water changes with temperature, and explain why ice forms at the surface of oceans and lakes. **Instruments, Measurements, and Representations** **Technical Vocabulary** Surface tension and capillary action **Clarifications**
Content Statement **E1.3p: Landforms and Soils (*Middle School*) –** Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruptions and deposition of sediments transported in rivers, streams and lakes through watersheds. Destructive forces include weathering and erosion. The weathering of rocks and decomposed organic matter result in the formation of soils. *(prerequisite)* ***Identifying and Using Performance Expectations*** **E1.3p1** Explain the origin of local landforms. Describe and identify surface features using maps and satellite images. **E1.3p2** Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments. **E1.3p3** Describe how coastal features are formed by wave erosion and deposition. **Instruments, Measurements, and Representations** **Technical Vocabulary** <u>Exclusions</u>	

Names of soil types. **Clarifications** Focus on mechanisms that build up and tear down Earth structures	
E ***Content Statement*** **1.4 Earth Systems Overview –** The Earth is a system consisting of four major interacting components-- geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Plans for land use and long-term development must include an understanding of the interactions of Earth systems with human activities. ***Identifying and Using Performance Expectations*** **E1.4A** Compare an open and closed system and explain why Earth is essentially a closed system. **E1.4B** Describe the major systems (geosphere, hydrosphere, biosphere, atmosphere) that make up the Earth. **E1.4C** Explain, using specific examples, how a change in one system affects other Earth systems. **E1.4D** Describe how the interaction of physical processes and human activities impact water, land and air. **Instruments, Measurement, and Representations** Diagrams showing the connection of the different cycles of the Earth systems **Technical Vocabulary** **Clarifications**	***Content Statement*** **E1.4x Earth Systems –** Interactions between the systems have resulted in ongoing evolution of the earth system over geologic time. ***Identifying and Using Performance Expectations*** **E1.4e** Explain how feedback loops affect systems. **Instruments, Measurement, and Representations** Models of the evolution of earth systems over the geological time scale **Technical Vocabulary** **Clarifications** Focus: on the length of time it takes for certain elements to cycle through the Earth system and show how it has changed through geological time
Inquiry, Reflecting, and Technology Performances	
E1.R1 Write the geologic history for your area based on rock types using Michigan geologic (bedrock) maps and local data. **E1.R2** Make a model, illustrating the processes that transport water between reservoirs in the water cycle. This model should be based on local water sources and include the drinking water supply for your community. **E1.R3** Justify a community land use plan considering risks and benefits.	**E1.r4** Map a feedback loop in an Earth system

Standard E2: The Solid Earth

Standard Statement

Students will explain how scientists study and model the interior of the Earth and its dynamic nature. They will use the theory of plate tectonics, the unifying theory of the Earth Sciences, to explain a wide variety of Earth features and processes and how hazards resulting from these processes impact society.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E2.1 Structure of the Earth** –The Earth is composed of a series of concentric layers classified by their chemical composition (crust, mantle and core) or based on their physical characteristics: (lithosphere, asthenosphere, lower mantle, outer core, and inner core). The crust and upper mantle compose the rigid lithosphere that moves over a "softer" asthenosphere (part of the upper mantle). The dynamic interior of the Earth cannot be directly sampled and must be modeled using data from seismology. ***Identifying and Using Performance Expectations*** **E2.1A** Explain how scientists infer that the Earth has interior layers. **E2.1B** Explain the uncertainties associated with models of the interior of the Earth and how these models are validated. **Instruments, Measurements, and Representations** Cross sections and scales. Models of the Earth's interior. **Technical Vocabulary** crust, mantle, outer core, inner core, lithosphere, asthenosphere. **<u>Exclusions</u>** All other minor subdivisions in the crust and mantle (e.g., transition zone, Moho, D"). **Clarifications** The crust-mantle-core subdivision of the Earth is based on chemical composition (seismic velocity) while the lithosphere and asthenosphere are distinguished on the basis of rock behavior.	***Content Statement*** **E2.1x The Interior of the Earth** – Plate motions are driven by forces acting primarily along their boundaries using energy derived from convective heat transfer. The pattern of convection in the mantle can be inferred from the speeds at which earthquake waves travel through the Earth. ***Identifying and Using Performance Expectations*** **E2.1c** Explain how patterns of convection in the mantle are determined. **E2.1d** Predict general regions of rising and sinking upper mantle material using the distribution of plate boundaries. **Instruments, Measurements, and Representations** Seismographs and seismograms **Technical Vocabulary** Elastic, viscous, and plastic behavior Terms for mechanisms of heat transfer such as convection, conduction and radiation relative and absolute plate motions **Clarifications** Plates are part of the convection system.

Content Statement

E2.2 Plate Motions – Plates are composed of the lithosphere and move at velocities of cm/yr as measured using the global positioning system. Oceanic plates are created at mid-ocean ridges and cool until they sink back into the Earth at subduction zones. At some localities, plates slide by each other. Mountain belts are formed both by continental collision and as a result of subduction. The outward flow of heat from the Earth provides the driving energy for plate tectonics.

Identifying and Using Performance Expectations

E2.2A Describe how the direction and the rate of movement for the plate on which you live has affected the local climate over the last 600 million years.

E2.2B Explain how plate tectonics accounts for the features and processes (sea floor spreading, mid ocean ridges subduction zones, earthquakes and volcanoes, mountain ranges) that occur on or near the Earth's surface.

E2.2C Describe how the transfer of heat from inside the Earth could result in plate movements.

Instruments, Measurements, and Representations

Relative and absolute motion (frames of reference)

Topographic (including the ocean floor showing ridges and trenches) and geologic maps, cross sections (topographic and geologic), satellite imagery of plate boundary structures.

Cross sections of plate boundaries

Maps of plate motions

GPS systems

Technical Vocabulary

Types of plate boundaries (convergent, divergent, transform), processes (subduction, sea-floor spreading, rifting), and physiographic features (mid-ocean ridge, trench, island arc, etc.) associated with them. Relative plate motions.

<u>Exclusions</u>

Names of specific plates except North America, Pacific, and Eurasia.

Clarifications

Focus: On the evidence for plate movements and their relationship to mountain building, earthquakes, island arcs, and volcanoes. Plate movements are driven by convective heat transfer in the mantle (specific mechanism is covered in XE2.1)

Content Statement

E2.2x Plate Motions – The magnetic field of the earth, which is believed to originate in the outer core, is a dipole which reverses direction approximately every million years. This helps us demonstrate that continents have moved and that new ocean floor is created at mid-ocean ridges. Plate motions have also been determined using volcanic islands.

Identifying and Using Performance Expectations

E2.2d Determine the rate of sea-floor spreading, using the correlation of magnetic anomalies and the magnetic reversal time scale.

E2.2e Describe the paleomagnetic evidence for continental drift.

E2.2f Explain how linear island chains can be explained by the hot spot model

Instruments, Measurements, and Representations

compass, GPS systems

Maps of magnetic orientation of rocks on both sides of a mid-ocean ridge

Calculations of spreading rate using magnetic lineations and distance from the ridge

Maps showing radiometric dates of rocks on different Hawaiian islands.

Know about magnetometers, radiometric dating methods, and GIS systems.

Technical Vocabulary

Geographic and magnetic north; dipole, magnetometer, magnetic anomaly (or lineation)

<u>Exclusions</u>

details of radiometric dating methods

Clarifications

Focus on evidence for sea-floor spreading and continental movements

Content Statement

E2.3x Plate Evolution – Oceanic plates cool as they move away from the ridge. Accretion of material to the continents can occur at subduction zones.

	Identifying and Using Performance Expectations **E2.3a** Predict the temperature distribution in the lithosphere as a function of distance from the mid-ocean ridge. **Instruments, Measurements, and Representations** Graphs of the temperature distribution in the lithosphere Geologic maps **Technical Vocabulary** Mechanisms for heat transfer (convection, conduction, radiation), relative plate motions. Link to physics. **Clarifications** Focus on how oceanic lithosphere evolves and how do continents grow.
Content Statement **E2.4 Earthquake and Volcanic Hazards** – Plate motions result in potentially catastrophic events (earthquakes, volcanoes, tsunamis) that affect humanity. Prediction of these events largely depends on periodicity (historically, how often they have occurred) and the identification of precursory phenomena (warning signs). ***Identifying and Using Performance Expectations*** **E2.4A** Use the distribution of earthquakes and volcanoes to locate plate boundaries **E2.4B** Explain how volcanic eruptions can affect climate **E2.4C** Describe how the sizes of earthquakes and volcanoes are measured or described. **E2.4D** Describe the effects of earthquakes and volcanic eruptions on humans **E2.4E** Describe safety procedures for earthquakes and volcanoes **Instruments, Measurements, and Representations** Know about instruments such as seismographs, laser ranging systems, tiltmeters used in recording earthquakes and forecasting volcanic eruptions Quantitative measures of earthquake size (intensity and magnitude) Map projections and maps of earthquake and volcano distribution and their relationship to plate boundaries, topography, and hazards Seismograms **Technical Vocabulary** Terminology for common hazards of earthquakes and volcanoes (e.g., mud flows, landslides, tsunami, subsidence, debris flow, liquefaction), terms for simple precursory phenomena for both earthquakes (foreshocks, radon release, etc.), and volcanoes (earthquakes, gases, etc.).	***Content Statement*** **E2.4x Earthquakes and Volcanoes** – The intensity of volcanic eruptions are controlled by the chemistry and properties of the magma. Igneous rocks are created from magmas both below and on the surface of the Earth. Earthquakes are the result of abrupt movements of the Earth and generate energy in the form of body and surface waves. Plate movements also affect climate and ocean circulation on long time scales ***Identifying and Using Performance Expectations*** **E2.4f** Explain how the chemical composition of magmas affects explosivity. **E2.4g** Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems. **E2.4h** Explain why fences are offset after an earthquake, using the elastic rebound theory. **E2.4i** Determine the epicenter of earthquakes using P- and S-wave arrival times. **Instruments, Measurements, and Representations** Know about tiltmeters, seismographs, tsunami detection bouys, satellites, etc. **Technical Vocabulary** silica content of magmas, VEI scale. General characteristics of end-member volcano types. Terminology related to earthquake prediction (Dilatancy, strain accumulation, creep) and description of volcanic eruptions (pyroclastic flow) Elastic, viscous, and plastic behavior Moment magnitude, **Clarifications** Focus on what controls how severe a hazard will be and why

Magnitude and intensity, volcano explosivity index. Associated content from physics – waves and wave descriptors **Exclusions** Different magnitude and intensity scales (except for moment magnitude). Specific names for types of volcanic eruptions or names of igneous rocks. **Clarifications** Focus on understanding the natural processes that cause hazards, specific effects of hazards, and the warning signs of an impending disaster	

Inquiry, Reflecting, and Technology Performances	
E2.R1 Make observations (sound, mass, etc.) of a hidden physical model and infer the internal characteristics of the model. **E2.R2** Develop a scale model based on data that describes the nature of the Earth's interior. **E2.R3** Design model structures that would be resistant to horizontal shaking. **E2.R4** Evaluate the consequences of erroneous or spurious forecasts of natural hazards. **E2.R5** Investigate how plate motions impact oceanic circulation, weather, climate, and the distribution of natural resources.	**E2.r6** Predict how the passage of seismic waves through the Earth would differ if the lower mantle was also a fluid. **E2.r7** Develop a hypothesis for why the continental geology near subduction zones is complex, using geologic map data. **E2.r8** Develop a model for the generation of tsunamis.

Standard E3: The Fluid Earth

Standard Statement

Students will explain how the ocean and atmosphere move and transfer energy around the planet. They will also explain how these movements affect climate and weather and how severe weather impacts society. Students will also explain how long term climatic changes (glaciers) have shaped the Michigan landscape.

Content Statements, Performances, and Boundaries

Essential	**Core**
Content Statements, Identifying and Using Performances	
Content Statement **E3.1 Oceans** – Oceans redistribute matter and energy around the Earth, through surface and deepwater currents, waves, and interaction with other Earth systems. Motion of the ocean is controlled by temperature, density, gravity, Coriolis effect, and coupling with the atmosphere. Oceans and large lakes (e.g., Great Lakes) have a major effect on climate and weather because they are a source of moisture and a large reservoir of heat. Interactions between oceanic circulation and the atmosphere can affect regional climates throughout the world (e.g., El Nino).	***Content Statement*** **3.1x Oceans and Coastlines** – The ocean covers a large portion of the Earth's surface and contains almost all of its water. Ocean water is salty as a result of chemical weathering and volcanic eruptions. Different zones in the ocean can be described by differences in density, temperature, light penetration, oxygen content, etc. Tides and waves erode the shoreline and beaches.

Identifying and Using Performance Expectations **E3.1A** Explain the relationship between El Nino and changes in ocean circulation. **E3.1B** Explain how the Coriolis effect controls oceanic circulation. **E3.1C** Explain the dynamics of oceanic currents, including upwelling, density, and currents, and their relationship to global circulation **E3.1D** Identify factors affecting seawater density and salinity and describe how density affects oceanic layering. **Instruments, Measurements, and Representations** Maps of ocean circulation and ocean-atmosphere interactions Climate maps showing data such as snowfall, prevailing wind direction, temperatures Common terms such as El Nino, La Nina, and Gulf Stream **Clarifications**	***Identifying and Using Performance Expectations*** **E3.1e** Identify types of shoreline structures (dikes, breakwaters, etc.) and describe the effects they have on shorelines. **E3.1f** Summarize how waves originate and know wave terminology. Understand orbital motion and the difference between deep- and shallow-water waves. **E3.1g** Explain the differences between maritime and continental climates **E3.1h** Describe thermohaline (deep ocean) circulation and explain how and where water masses are produced. **E3.1i** Explain how El Nino affects economies (in South America for example). **Instruments, Measurements, and Representations** Know about echo sounding, Seasat, underwater probes and submersibles, GIS Computer simulations of mechanisms that produce El Niño-Southern Oscillation (ENSO) and La Nina events. **Technical Vocabulary** salinity **<u>Exclusions</u>** specific % for water in various reservoirs, specific concentrations **Clarifications**
Content Statement **E3.2p Weather and the Atmosphere (*Middle School*) –** The atmosphere is divided into layers defined by temperature. Clouds are indicators of weather. *(prerequisite)* ***Identifying and Using Performance Expectations*** **E3.2p1** Describe the layers of the atmosphere. **E3.2p2** Explain the differences between fog and dew formation and cloud formation. **E3.2p3** Describe relative humidity in terms of the moisture content of the air and the moisture capacity of the air and how these depend on the temperature. **Instruments, Measurements, and Representations** Weather map reading and interpretation	***Content Statement*** **3.2x Global Circulation and Climate** – Energy from the sun, differential heating, and the rotation of the Earth control global atmospheric circulation. Climate is controlled by the general circulation of the atmosphere as well as static conditions such as the positions of mountain ranges and bodies of water. Global climate models are being developed that can predict climate over decades into the future. Regional models are used for more localized studies. ***Identifying and Using Performance Expectations*** **3.2a** Identify the main sources of energy to the climate system **3.2b** Identify the effects of various physical parameters (such as air pressure, temperature, CO2) using a computer simulation. **3.2c** Explain how climate results from the interaction among the different components of the Earth system. **3.2d** Explain feedback mechanisms and their role in the climate system. **3.2e** Provide examples of how the unequal heating of the earth and the Coriolis effect influence circulation patterns, and show their impact on Michigan weather and climate. **Instruments, Measurements, and Representations** Global and regional climate models

Diagrams and illustrations to determine the differences between cloud types

Simple instruments such as wind gauges, barometers

Models of planetary motion to demonstrate seasons

Maps of global wind patterns

Technical Vocabulary

Common terms including major atmospheric layers (troposphere and stratosphere, ozone layer, jet stream) and names of weather instruments

Common cloud names such as stratus, cumulus, alto, nimbus, cirrus, fog, dew

Technical terms for weather and climate may be introduced but emphasis should be on understanding the processes rather than knowing the names of the processes

Clarifications

Maps and models of atmospheric circulation

Technical Vocabulary

Convection cells, trade winds, westerlies, polar easterlies, land/sea breezes, mountain/valley breezes, jet stream, weather map reading and interpretation, Coriolis effect.

Clarifications

Content Statement

E3.3 Severe Weather – Tornadoes, hurricanes, and thunderstorms are severe weather phenomena that impact society and ecosystems. Hazards include downbursts (wind shear), strong winds, hail, lightning, heavy rain and flooding. The movement of air in the atmosphere is due to differences in air density resulting from variations in temperature. Many weather conditions can be explained by fronts that occur when air masses meet.

Identifying and Using Performance Expectations

E3.3A Describe the various conditions of formation associated with tornadoes, hurricanes, thunderstorms, drought and heat, and floods, their impacts.

E3.3B Describe the damage resulting from, and the societal impact of, hurricanes, floods, and tornadoes.

E3.3C Describe conditions associated with frontal boundaries that result in severe weather.

E3.3D Describe how mountains, frontal wedging (including dry fronts), convection, and convergence to form clouds and precipitation.

E3.3E Describe severe weather and flood safety and mitigation.

Instruments, Measurements, and Representations

Know about radar (distinguish doppler and reflectivity),

Weather map reading and interpretation

Topographic maps of flood plains

Technical Vocabulary

high and low pressure areas, fronts, rotation, heat transport

<u>Exclusions</u>

details of windspeeds, storm surges, etc., associated with Saffir-Simpson and Fujita scales.

Content Statement

E3.3x Mesometeorology – Many weather conditions can be explained by fronts that occur when air masses meet. Tornadoes and hurricanes are both heat transfer mechanisms. Additional longer term hazards include severe cold, severe heat and drought. Prediction of severe weather is dependent on the identification of instability in the atmosphere. Regional weather and climate can be impacted by topography and land use.

Identifying and Using Performance Expectations

E3.3f Explain the process of adiabatic cooling and adiabatic temperature changes to the formation of clouds.

Instruments, Measurements, and Representations

satellite imagery (visible, IR, water vapor), computer simulations (Global climate models)

Weather map, vertical profiles (soundings), and satellite image (remote sensing) reading and interpretation.

Tools such as pyschrometer to determine the relative humidity

Computer simulations of the effects of topographic features and land use on regional weather

Technical Vocabulary

Common terms such as adiabatic cooling and orographic lifting, frontal wedging (including dry fronts), convection currents, and convergence lifting

descriptive terminology such as relative humidity, dew point

Clarifications

Focus: on weather conditions that explain fronts and the movement of air masses that lead to the development of severe weather.

Clarifications Severe weather has extensive impacts on society as a whole.	
Content Statement **E3.4 Glaciers –** Glaciers are large bodies of ice that move under the influence of gravity; they form part of both the rock and water cycles. Glaciers and ice sheets have shaped the landscape of the Great Lakes region. (see also climate change) ***Identifying and Using Performance Expectations*** **E3.4A** Describe how glaciers have affected the Michigan landscape and how the resulting landforms impact our state economy. **E3.4B** Explain the formation of the Great Lakes. .**Instruments, Measurements, and Representations** Maps, diagrams or charts showing the advance and retreat of the Great Lakes and ice sheets Topographic and geologic maps showing landforms due to glaciation (e.g., kettle lakes, drumlins and moraines). **Technical Vocabulary** Common glacial landforms (e.g., moraine, kettle lakes, drumlin, etc.) Common glacial descriptors such as continental, alpine, ice sheet **Clarifications** Focus on ice sheets and Great Lakes geomorphology as evidence for the last ice age.	***Content Statement*** **E3.4x Glacial Rebound –** Areas that have been occupied by ice sheets are depressed; when the ice sheet is removed, the region uplifts according to the principle of isostasy. ***Identifying and Using Performance Expectations*** **E3.4c** Explain what happens to the lithosphere when an ice sheet is removed. **Instruments, Measurement, and Representations** Mathematical formulation of isostasy Lake level gauges, tiltmeters Charts of data for the thickness of glacial ice sheets to calculate the isostatic rebound of the Great Lakes region. Soil and sediment maps and their relationship to glaciation. **Technical Vocabulary** glacial rebound, isostasy, deglaciation, glaciers. **Clarifications**
Inquiry, Reflecting, and Technology Performances	
E3.R1 Identify areas subject to lake effect precipitation, using snowfall data (e.g., from western Michigan) and prevailing wind direction. **E3.R2** Develop land use criteria for a flood plain. **E3.R3** Investigate possible mitigation strategies for hurricanes, floods, and tornadoes. **E3.R4** Determine the direction of ice or water flow in the Great Lakes region, using topographic maps. **E3.R5** Develop a model showing how a glacier moves	**E3.r6** Apply tornado damage reports and map its path and history. **E3.r7** Illustrate and explain both current weather conditions and forecasting, using satellite and radar images and weather maps. **E3.r8** Investigate the effects of topographic features and land use on regional weather, using a computer simulation. **E3.r9** Design structures that are more resistant to hurricane and straight line winds. **E3.r10** Using the thickness of the glacial ice sheets, calculate the isostatic rebound in the Great Lakes region.

Standard E4: The Earth in Space and Time

Standard Statement

Students will explain how the Earth and universe formed and evolved over a long period of time. Students will predict how human activities may influence the climate of the future.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Performances, and Boundaries	
Content Statement **E4.1 Sky Observations (*Middle School*) –** Common sky observations (such as lunar phases) can be explained by the motion of solar system objects in regular and predictable patterns. Our galaxy, observable as the Milky Way, is composed of billions of stars, some of which have planetary systems. Seasons are a result of the tilt of the rotation axis of the Earth. ***Identifying and Using Performance Expectations*** **E4.1A** Describe the motions of various celestial bodies and some the effects of those motions (MS) **E4.1B** Explain the primary cause of seasons. **Instruments, Measurement, and Representations** Telescopes and binoculars to see stars, nebulae, and galaxies Space probes and satellites to obtain images of stars, nebulae, and galaxies. **Technical vocabulary** Common terms such as constellation, revolution, nebula, star cluster, galaxies **Clarifications** Focus: use what we see from Earth to explain phenomena such as the movement of constellations and moon phases	***Content Statement*** **E4.1x Planetary Motion** Kepler's Laws of Motion can be used to mathematically represent the motions of bodies in the universe under the influence of gravity. ***Identifying and Using Performance Expectations*** **E4.1c** Predict the orbit of bodies in the solar system, using Kepler's Laws. **E4.1d** Describe how a change in the Earth's orbit or its axis of rotation affect climate **Instruments, Measurement, and Representations** Mathematical representations such as Kepler's Laws, force and gravitational equations **Technical Vocabulary** Retrograde motion, axial retrograde and moon retrograde **Clarifications** Focus: on mathematically representing the motions of planets
Content Statement **E4.2 The Earth in Space –** Scientific evidence indicates the universe is orderly in structure, finite, and contains all matter and energy. The sun provides energy to the Earth. The motions of the moon and sun affect the phases of the moon and ocean tides. Information from the entire light spectrum light tells us about the composition and motion of objects in the universe. Early in the history of the universe, matter clumped together by gravitational attraction to form stars and galaxies. The universe has been continually expanding at an increasing rate since its formation about 13.7 billion years ago. ***Identifying and Using Performance Expectations*** **E4.2A** Describe how nuclear fusion and other processes in stars have led to the formation of all the other chemical elements	***Content Statement*** **E4.2x Studying the Universe.** Information from the entire light spectrum light tells us about the composition and motion of objects in the universe. ***Identifying and Using Performance Expectations*** **E4.2d** Explain the characteristics of EM waves (photon energy, refractive characteristics of waves, attenuation) **E4.2e** Explain the nature (energy – longer wavelengths has a lower energy etc., refraction) of EM waves and their

E4.2B Describe the position and motion of our solar system in our galaxy and the overall scale, structure, and age of the universe.

E4.2C Describe a theory for the formation of the Universe.

Technical Vocabulary

Tropics, sunrise/sunset points, solar path and noon altitudes. Phase and moonrise time.

Instruments, Measurement, and Representations

Telescopes and binoculars to see the lunar surface and phases
Charts such as phase and moonrise times
Types of telescopes (optical, radio, space), spectroscopes to determine electromagnetic spectra
Spectroscopes to measure the speed of stars and galaxies moving away or toward us
Interpretation of graphs in terms of relationships (e.g., distance to galaxies vs. red shift)

Technical Vocabulary

Common terms such as electromagnetic spectrum,
spectroscopes, and magnitude radio waves, light, spectra
Names of light elements (e.g., hydrogen, helium), fusion, radiation, red shift, big bang.

Clarifications

Focus: use the entire light spectrum to determine stellar composition and characteristics and observational evidence and physics concepts that support the Big Bang theory

behaviors

E4.2f Describe the advantages and disadvantages of various instruments to study space (e.g., telescopes, spectrographs) and what they tell us about the structure and composition of objects in space.

E4.2g Compare and contrast two EM waves based on energy, travel paths, wavelength, and velocity

E4.2h Explain how spectra are used determine the temperature and composition of stars.

E4.2i Explain how a light year can be used as a distance unit.

Instruments, Measurement, and Representations

Charts such as phase and moonrise times
Types of telescopes (optical, radio, space)
Mathematical representations such as inverse square relationship
Spectroscopes to determine the chemical composition and to measure the speed of stars and galaxies moving away or toward us
Interpretation of graphs in terms of relationships (e.g., distance to galaxies vs. red shift, comparing magnitudes of starts to determine distance)
Computer simulations of the formation of galaxies and the Big Bang

Technical Vocabulary

Clarifications

Content Statement

E4.3x Stars – Stars, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. These and other processes in stars have led to the formation of all the other chemical elements. There are a wide range of stellar objects of different sizes and temperatures. Stars have varying life histories based on these parameters.

Identifying and Using Performance Expectations

E4.3a Explain how the H-R diagram can be used to deduce other parameters (distance, etc.).

E4.3b Explain how you can infer the temperature, life span and mass of a star, and its mass from its color. Use the H-R diagram to explain the life cycles of stars.

	E4.3c Explain how the balance between fusion and gravity controls the evolution of a star (equilibrium) **E4.3d** Compare the evolution paths of low, moderate and high mass stars using the H-R diagram. **E4.3e** Compare and contrast the final three outcomes of stellar evolution based on mass (black hole, neutron star, white dwarf). **E4.3f** Identify patterns in solar activities (sun spots, solar flares and relate patterns to effects on Earth. **Instruments, Measurement, and Representations** Radio, optical and other types of telescopes, spectroscopes to determine the composition of stars Images taken by large or space-based telescopes and spectra of stars and galaxies Interpretation of graphs in terms of relationships (e.g., brightness vs. temperature) Computer simulations of processes in stars **Technical Vocabulary** red giant, pulsar, planetary nebula, nebula, supernovas, nuclear fusion Magnitude, **Clarifications** Focus: use observational evidence and physics concepts to support theories about how stars shine
	Content Statement **E4.4x Magnetosphere** – The magnetic field of the Earth partially shields the Earth from harmful radiation. Solar flares are associated with sunspots and intensify the solar wind. Interactions between charged particles from the sun and the Earth's atmosphere produce auroras. ***Identifying and Using Performance Expectations*** **E4.4a** Explain solar wind and its effect on "space weather" **Instruments, Measurement, and Representations** Compass to measure the direction of the magnetic field Magnetometer on the surface of Earth and flown on spacecraft to measure strength and direction of magnetic field Computer simulations of magnetic field generation Solar magnetograms or simple solar telescopes or internet images to analyze sunspot activity to predict times of increased solar activity **Technical Vocabulary** Terms such as aurora, geomagnetic storm, magnetosphere, magnetopause, and magnetometer, sunspot cycle, magnetogram, solar flare, space weather **Clarifications** Focus: on generation, strength, and direction of the magnetic field

	Content Statement **E4.5x Evidence for the Nature of the Universe –** Evidence for the nature of the universe comes from a variety of observations of mass and light. ***Identifying and Using Performance Expectations*** **E4.5a** Differentiate between the cosmological and Doppler red shift. **E4.5b** Explain how observations of the cosmic microwave background have helped up determine the age of the universe. **E4.5c** Explain how dark energy and dark matter support the big bang theory. .**Technical Vocabulary** Red shift, Hubble's law, nucleosynthesis (fusion), dark energy, dark matter, big bang, red shift. **Clarifications**
	Content Statement **E4.6x Planetary Geology** – There are a wide variety of non-stellar objects in the solar system and the universe, including comets, asteroid, meteors, planets and their satellites. They fall into two general categories: rocky objects like the inner planets, moons, asteroids and meteors, and large gaseous objects like the outer planets. They can be studied through probes and other remote observations. ***Identifying and Using Performance Expectations*** **E4.6a** Describe and explain the structure of planetary bodies and terrestrial satellites. **E4.6b** Describe the early evolution of the solar system and the segregation into terrestrial and jovian types of planets. **E4.6c** Differentiate between meteoroids, comets, asteroids, minor moons of planets and Kuiper Belt objects. How are they different? How are they similar? How might one evolve into another? **Instruments, Measurement, and Representations** Telescopic and spacecraft-based photos of planets, moons, and comets. Fly-by based spectral and geodetic data. **Technical Vocabulary** **Clarifications** Focus: Variability of the geology, tectonism, and atmospheres of planets and satellites. Evidence for the existence of extra-solar planets
Content Statement **E4.7 Earth History and Geologic Time –** The Solar System formed from a nebular cloud of dust and gas 4.6 Ga (billion years ago). The Earth has changed through time and has been affected by both catastrophic (earthquakes, meteorite impacts, volcanoes, etc.) and gradual geologic events (plate movements, mountain	***Content Statement*** **E4.7x Geologic Dating** – Early methods of determining geologic time, such as the use of index fossils and stratigraphic principles, allowed for the relative dating of geological events. However, absolute dating was impossible until the discovery that certain radioactive isotopes in rocks have known decay rates, making it

building, etc.) as well as the effects of biological evolution (formation of an oxygen atmosphere, etc.). Geologic time can be determined through both relative and absolute dating. ***Identifying and Using Performance Expectations*** **E4.7A** Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago). **E4.7B** Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them **E4.7C** Relate major events in the history of the Earth to the geologic time scale (e.g., formation of the Earth, formation of an oxygen atmosphere, rise of life, major extinctions). **Instruments, Measurement, and Representations** Graphical representations of the structure, scale and composition of the solar system Topographic maps, geologic maps, geologic cross-sections, geologic columns Cross sections to reconstruct the sequence of events using stratigraphic principles Stratigraphic sections and index fossils to correlate the geologic history of a region Charts of long time spans to demonstrate “deep time” **Technical Vocabulary** Accretion Include vocabulary associated with geology and principles of relative dating, as well as relevant terms from life and physics. Can use names of Eras (Pre-Cambrian, Paleozoic, Mesozoic and Cenozoic) **Exclusions** Names of geologic Periods (Cambrian, Mississippian, etc) should be avoided unless relevant (e.g., K-T extinction event) , names of specific life forms (stromatolites, etc.), and specific processes of radioactive decay **Clarifications** Focus on how the Earth was formed from a nebular cloud of dust, the evidence for measuring geologic time and determining a sequence of events, and on understanding how geological processes work over a long time span; relate to the rock and water cycles.	possible to determine how many years ago a given mineral or rock formed. Different kinds of radiometric dating techniques exist; which is used depends on the material to be dated, the age of the material, and what geologic event that affected the material is being dated. ***Identifying and Using Performance Expectations*** **E4.7d** Determine the approximate age of a sample, when given the half-life of a radioactive substance (in graph or tabular form) along with the ratio of daughter to parent substances present in the sample. **E4.7e** Explain why can C-14 be used to date a 40,000 year old tree but the U-Pb can not. **Instruments, Measurement, and Representations** Graphical representation of radioactive decay, in particular different isotopes such as carbon-14 versus U-Pb, and use thereof as a tool to determine the age of a rock sample given ratios of different isotopes in a mineral. **Technical Vocabulary** Common terms such as radioactive decay, isotope, carbon-14, uranium-lead dating **Clarifications** Focus on understanding the principle behind dating techniques
	Content Statement **E4.8x The Early Earth –** Early Earth was very different from today’s planet. Evidence for one-celled forms of life—the bacteria— extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of Earth's atmosphere, which did not originally contain oxygen.

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Identifying and Using Performance Expectations

E4.8a Describe the evolution of the atmosphere.

Instruments, Measurement, and Representations

Technical Vocabulary

Common terms such as oxygen, one-celled bacteria, atmosphere, and evolution

Clarifications

Focus: on the development of Earth's atmosphere and the evolution of life

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Content Statement

E4.9 Climate Change – Changes in climate have profound effects on society. Carbon dioxide and other "greenhouse" gases trap reradiated energy from the Earth's surface and increase atmospheric temperature. Human activities can greatly increase the concentration of greenhouse gases. Climates of the past cannot be directly measured, but must be inferred.

Identifying and Using Performance Expectations

E4.9A Distinguish between natural (Milankovich cycles) and human-induced (greenhouse effect) climate changes

E4.9B Explain the causes of short-term climate changes such as catastrophic volcanic eruptions and impact of solar system objects.

E4.9C Describe the evidence for ice ages from geology (e.g., geomorphology, striations, and fossils).

E4.9D Describe the difference between weather and climate.

E4.9E Determine the empirical relationship between the emission of the three important greenhouse gases (carbon dioxide, methane, nitrous oxide) and global temperature

E4.9F Predict the global temperature increase by 2100, given data on the annual trends of CO_2 concentration increase.

Instruments, Measurement, and Representations

Graphs of temperature changes over time
Models showing global climate change
Maps of major atmospheric and oceanic currents from the past through to the present
Charts of data to calculate the impact on sea-level of the melting of ice caps and glaciers in various parts of the world.
Computer models to investigate feedback mechanisms associated with global warming/climate change.

Technical Vocabulary

Common terms such as methane, carbon dioxide, greenhouse effect, feedback mechanisms, and global warming

Clarifications

Focus: on what global warming is and causes for

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Content Statement

E4.9x Determination of Paleoclimate – Climates of the past can be determined by indirect indicators such as isotopic ratios in foraminifera, gas bubbles, etc. These have been correlated with variations in the insolation of the Earth. Major ice sheets can also affect the surface of the Earth after they are removed.

Identifying and Using Performance Expectations

E4.9g Use Oxygen isotope data to estimate paleo-temperature

E4.9h Explain how the climates of the past (e.g., ice ages) can be determined using proxy indicators (e.g., oxygen isotopes, CO_2 content of the atmosphere)

Instruments, Measurement, and Representations

Charts and tables Oxygen isotope data to estimate the paleo-temperature

Technical Vocabulary

Common terms such as paleoclimate, proxy indicators, and foraminifera, oxygen isotopes

Clarifications

Focus on the reliability of proxy indicators to determine paleoclimate.

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global warming in the present and past. See also glaciers.	
Inquiry, Reflecting, and Technology Performances	
E4.R1 Create a model of the Earth-Moon-Sun system that can be used to predict moon phases tides, and local time. **E4.R2** Reconstruct the sequence of events using stratigraphic principles and data from a geologic cross section.. **E4.R3** Construct and analyze a time line for the Earth that indicates both the relative and absolute times of the events. .**E4.R4** Investigate the possible consequences of global warming both on society and on natural ecosystems.	**E4.r5** Construct a regional geologic history, using index fossils and correlation, given data from disconnected stratigraphic sections. **E4.r6** Use a drawing of rock layers with the location of fossils from an extinct prehistoric animals, along with dates of volcanic rock layers determined by radioisotope methods above and below the fossils, to determine the upper and lower bounds of time during which the extinct animal lived **E4.r7** Apply Hubble's Law to verify that the universe is expanding **E4.r8** Describe the likelihood and consequences of an impact event. **E4.r9** Design an experiment to detect extra-solar planets using light and gravitational effects.

Standard E5: Chemicals in the Environment

Standard Statement

Students will explain how chemicals move through Earth systems as parts of many processes and cycles and the energy that drives them. Students will also describe human uses of energy and other resources and evaluate the consequences of their use.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E5.1 Chemicals in the Earth System (Geochemical Cycles) –** The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and forms; they move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of the earth system. The movements within the cycles can be slow or rapid and are often accompanied by changes in the physical and chemical properties.	***Content Statement*** **E5.1x Biogeochemical cycles –** Many chemicals have significant impacts on the biosphere and have important impacts on human health.
Identifying and Using Performance Expectations **E5.1A** Explain how chemicals are found in different forms in different parts of the earth system. **E5.1B** Explain how nitrogen and carbon move through the Earth System (including the geosphere) and how they may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society. ***Note: Additional performances associated with this content statement are embedded under other standards and expectation (see also below).***	***Identifying and Using Performance Expectations*** **E5.1c** Explain why small amounts of some chemicals may be necessary for health but are poisonous in large quantities. **E5.1d** Explain how certain chemicals in the Earth system (e.g., DDT, Pb) can affect human health.

Instruments, Measurements, and Representations Chemical tests and instruments to monitor quality of soil, water, and air and the health of ecosystems (e. g. wetlands, deserts, plains, rainforests, etc.) **Technical Vocabulary** decomposition, weathering, erosion, precipitation, evaporation, photosynthesis, transpiration, absorption, infiltration, respiration; other relevant terms from the rock and water cycles relevant terms from chemistry **Clarifications** Focus on interaction of Earth systems on a global scale with emphasis on tracing processes between systems and the energy sources that drive them.	**Instruments, Measurements, and Representations** Graphs and models of the movement of chemicals, oxygen, carbon dioxide, and carbon **Technical Vocabulary** Common chemicals such as potassium, sulfur, phosphorus, oxygen, and calcium **Clarifications** Focus on the health impacts of chemicals in the Earth system.
Content Statement **E5.2 Energy** – Movement of matter and its component chemicals, through and between Earth's systems is driven by Earth's internal (radioactive decay and gravity) and external sources (sun) of energy. Energy moves by radiation, convection and conduction. Fossil fuels are derived from plants and animals of the past and are non-renewable and limited in availability. Alternative fuels include solar and wind power, nuclear, ethanol, geothermal, and hydroelectric, etc. and have advantages and disadvantages. ***Identifying and Using Performance Expectations*** **E5.2A** Describe the Earth's principal sources of internal and external energy, e.g., radioactive decay, gravity, solar energy. **E5.2B** Describe how your electricity is generated. **E5.2C** Describe the processes by which fossil fuels are formed and why they are non-renewable. **E5.2D** Recognize, describe, and differentiate between renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy. **Instruments, Measurement, and Representations** Diagrams showing the flow of energy and matter through Earth systems and resulting phenomena Mathematical formula such as kinetic energy and potential energy Laws such as the first Law of Thermodynamics **Technical Vocabulary** Common physics terms such as kinetic energy, potential energy, heat, gravity. Renewable and non-renewable resources, nuclear power, ethanol **Clarifications** Focus on how energy moves through Earth systems and how some resources are non-renewable	***Content Statement*** **E5.2x Energy –** Energy can exist in numerous forms (heat, fossil fuels, tidal energy, etc.) and can be transformed from one state to another and move from one reservoir to another. ***Identifying and Using Performance Expectations*** **E5.2e** Explain how the first and second laws of thermodynamics affect the amount of energy available on Earth to do work. **E5.2f** Predict the change in state of a chemical as it moves from one reservoir to another. **E5.2g** State where in Earth systems energy transfer occurs by conduction, convection, radiation, radioactive decay and gravity. **Instruments, Measurement, and Representations** Laws such as the first and second Law of Thermodynamics should be understood **Technical Vocabulary** Common physics terms such as kinetic energy, potential energy, heat, gravity. **Clarifications** Focus on reservoirs that store energy.
Content Statement	***Content Statement***

E5.3 Human Effects on Earth Systems The Earth provides resources (including minerals) that are used to sustain human affairs. The supply of these resources is limited and their extraction and use can release chemicals into Earth systems. They affect air and water quality, ecosystems, landscapes, and may have effects on long-term climate. ***Identifying and Using Performance Expectations*** **E5.3A** Describe the effects on the environment of using both renewable and nonrenewable sources of energy. **E5.3B** Explain how human activities impact air, soil and water quality. **E5.3C** Explain how one human activity, for example, cutting down a large tract of forest for mining, can affect the entire Earth system. **E5.3D** Describe the life cycle of a product, including the resources, production, packaging, transportation, disposal, and pollution. **Instruments, Measurements, and Representations** Rain gauges, thermometers, etc. to measure and record attributes of an environment (e.g., patterns and changes in mean min/max monthly temperatures, rainfall, cloud coverage) and determine the quality of an environment Diagrams showing the life cycle of a product Appropriate chemical tests and instruments to monitor environmental quality – see geochemical cycles. **Technical Vocabulary** Common terms such as resource, production, fossil fuels, waste disposal, transportation, disposal, mining, reclamation, and ecosystems **Clarifications** Focus on how resource use affects humans by interfering with the quality of the Earth system .	**E5.3x Society and the Environment –** Humans impact the environment in a number of different ways. Alternative fuels and other energy sources may be necessary to carry us forward into the 22nd century. ***Identifying and Using Performance Expectations*** **E5.3e** Explain what makes a society sustainable. **E5.3f** Explain how soil erosion can result in desertification. **E5.3g** Explain how carbon dioxide sequestration may slow global warming. **E5.3h** Explain ozone depletion in the stratosphere and methods to slow human activities to reduce ozone depletion. **Instruments, Measurements, and Representations** Charts and data of resource use **Technical Vocabulary** resource, production, packaging, transportation, disposal, pollution, renewable and nonrenewable resources and terms associated with them **Clarifications** Focus on alternative fuels and new ideas for controlling pollution during production of resources.
Inquiry, Reflecting, and Technology Performances	
E5.R1 Develop strategies for reducing the dependence on fossil fuels **E5.R2** Evaluate long range plans for resource use and by-product disposal in terms of environmental and economic impact. **E5.R3** Propose methods for reducing air and water pollution.	**E5.r4** State the movement of simple ecosystem with the chemicals, oxygen, carbon dioxide, and carbon in a simple ecosystem, using a computer model. **E5.r5** Identify relationships and connections between the nitrogen, carbon, water, and rock cycles. **E5.r6** Determine why there may be a conflict between individual versus societal needs of resources. **E5.r7** Develop procedures to reduce waste. **E5.r8** Investigate feedback mechanisms associated with global warming/climate change, using computer simulations.

Michigan High School Science

BIOLOGY

Prerequisite, Essential, and Core

Content Statements and Expectations

CE • **RIGOR** • RELEVANCE • RELATIONSHIPS • RIGOR • RE
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MICHIGAN Department of Education

BIOLOGY (B)

The structure of living systems directly influences how they carry out their life functions. Reasoning about living systems often involves relating different levels of organization, from the molecule to the biosphere, and understanding how living systems are structured at each level. Cells are made of complex organic molecules and are the basic unit of life. Organisms can be either single-celled or multicellular. Multicelluar organisms have specialized cells to carry out specific functions.

Energy plays a crucial role in all aspects of every living thing, from the molecular to the global level. The food-making process of photosynthesis generates the energy source, in the form of organic compounds, for all living things. This energy is transferred in ecosystems via food chains and webs. The energy found in organic chemical bonds is changed to usable cellular energy through the process of cellular respiration.

Life processes in a cell are based on molecular interactions which keep the internal environment relatively constant. Cells are composed of highly organized structures called organelles. Cells are the smallest unit of life that can assimilate energy, reproduce, react to the environment, etc. A collection of cells with a common function form a tissue and several kinds of tissues form an organ. Together many organs form an organ system such as the digestive system. A multicellular organism is the composite of cells, tissues, and organs

It is essential that genetic information be passed from parents to offspring. This is accomplished as genetic material is passed from parent to offspring in the development of gametes and then fertilization units the genetic information from both parents creating a unique individual Organisms within a species are generally similar because they posses very similar genetic material. However, genetic mixing and occasional mutation result in differences among individuals. Over time, changes in genetic information can affect the size, diversity, and genetic composition of populations, a process called biological evolution.

Earth's present day life forms have evolved from common ancestors by a process of natural selection. Evolution is the unifying principle that provides the framework for organizing most of biological knowledge into a coherent picture. Evidence for evolution is found in the fossil record and is indicated by anatomical and chemical similarities evident within the diversity of existing organisms.

Outline of Biology Expectations

STRUCTURE AND FUNCTIONS OF LIVING SYSTEMS

Standard B1: Organization and Development of Living Systems

B1.1 Cellular Specialization
B1.2 Organic Molecules
B1.2x Proteins
B1.3 Maintaining Environmental Stability
B1.3x Homeostasis
B1.4 Cell Specialization
B1.5 Living Organism Composition
B1.5x ATP
B1.6x Internal/ External Cell Regulation

Standard B2: Interdependence of Living Systems and the Environment

B2.1 Ecosystems
B2.2 Element Recombination
B2.3 Changes in Ecosystems
B2.3x Human Impact
B2.4 Populations
B2.4x Environmental Factors

CHANGES IN LIVING SYSTEMS

Standard B3: Genetics

B3.1 Genetics and Inherited Traits
B3.2 DNA
B3.3x RNA and Protein Synthesis
B3.4 Sexual Reproduction
B3.5x Genetic Variation
B3.6x Recombinant DNA

Standard B4: Evolution and Biodiversity

B4.1 Theory of Evolution
B4.2 Molecular Evidence
B4.3 Natural Selection

Standard B1: Organization and Development of Living Systems

Standard Statement

Students describe the general structure and function of cells. They can explain that all living systems are composed of cells and that organisms may be unicellular or multicellular. They understand that cells are composed of biological macromolecules and that the complex processes of the cell allow it to maintain a stable internal environment necessary to maintain life. They make predictions based on these understandings.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **L*1.p1:** All organisms are composed of cells, from just one cell to many cells. Over two-thirds of the weight of a cell is accounted for by water, which gives cells many of their properties. In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of organisms for food, air, and waste removal. The way in which cells function is similar in all living organisms.*(Prerequisite)* ***Identifying and Using Performance Expectations*** ▪ Distinguish between living and nonliving systems. ▪ Explain the importance of both water and the element carbon to cells. ▪ Describe growth and development in terms of increase in cell number, cell size, and/or cell products ▪ Explain how the systems in a multicellular organism work together to support the organism. ▪ Compare and contrast how different organisms accomplish similar functions (e.g., obtain oxygen for respiration, excrete waste).	
Content Statement **L1.p2:** *Prerequisite:* Following fertilization, cell division produces a small cluster of cells that then differentiate by appearance and function to form the basic tissues of an embryo. ***Identifying and Using Performance Expectations*** ▪ Describe how through cell division, cells can become specialized for specific function. ▪ Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of	***Identifying and Using Performance Expectation*** ▪ Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.

the embryo.	
Content Statement **L1.p3:** *Prerequisite:* Cells carry out the many functions needed to sustain life. They grow and divide, thereby producing more cells. Food is used to provide energy for the work that cells do and is a source of the molecular building blocks from which needed materials are assembled. ***Identifying and Using Performance Expectations*** ▪ Describe how organisms sustain life by obtaining, transporting, transforming, releasing, and eliminating matter and energy. ▪ Describe the effect of limiting food to developing cells. ▪ Predict what would happen if essential elements were withheld from developing cells.	
Content Statement **L1.p4:** *Prerequisite:* Plants are producers—they use the energy from light to make sugar molecules from the atoms of carbon dioxide and water. Plants use these sugars, along with minerals from the soil, to form fats, proteins and carbohydrates. This food can be used immediately, incorporated into the cells of a plant as the plant grows, or stored for later use. ***Identifying and Using Performance Expectations*** ▪ Explain the significance of carbon in organic molecules. ▪ Explain the origins of plant mass. ▪ Predict what would happen to plants growing in low-carbon-dioxide atmospheres. ▪ Explain how the roots of specific plants grow. Content Clarification: Plants capture energy by absorbing light and using it to form chemical bonds between the atoms of sugar molecules. These sugar molecules can be used to make amino acids and other carbon-containing (organic) molecules and assembled into larger molecules with biological activity (including proteins, DNA, carbohydrates, and fats).	
Content Statement **L1.p5:** *Prerequisite:* All animals, including humans, are consumers, which obtain food by eating other organisms or their products. Consumers break down the structures of the organisms they eat to obtain the materials they need to grow and function. Decomposers, including bacteria and fungi, use dead organisms or their products for food. ***Identifying and Using Performance Expectations*** ▪ Classify different organisms based on how they obtain energy for growth and development. ▪ Explain how an organism obtains energy from the food it consumes.	
Content Statement **L1.p6:** *Prerequisite:* Living systems are made of complex molecules that consist mostly of a few elements, especially carbon, hydrogen, oxygen, nitrogen, and phosphorous.	

Identifying and Using Performance Expectations ▪ Recognize the six most common elements in organic molecules (C, H, N, O, P, S). ▪ Identify the most common complex molecules that make up living organisms. *** Please Note**: The code **L**1.p6 indicates the listed prerequisite is from anticipated middle school **Life** Science content statements. This is different than the **Biology** course content expectations, coded with a "**B**".	
Content Statement **B1.1 Cell Specialization** In multicellular organisms, cells are specialized to carry out specific functions such as transport, reproduction, or energy transformation. ***Identifying and Using Performance Expectations*** **B1.1A** Explain how cells transform energy (ultimately obtained from the sun) from one form to another through the processes of photosynthesis and respiration. Identify the reactants and products in the general reaction of photosynthesis. **B1.1B** Compare and contrast the transformation of matter and energy during photosynthesis and respiration. **B1.1C** Compare and contrast ways in which selected cells are specialized to carry out particular life functions. **B1.1D** Explain growth and development as a consequence of an increase in cell number, cell size, and/or cell products. **Technical Vocabulary** Energy transformation, reactant, product, growth, development	
Content Statement **B1.2 Organic Molecules** There are four major categories of organic molecules that make up living systems: carbohydrates, fats, proteins, and nucleic acids. ***Identifying and Using Performance Expectations*** **B1.2A** Explain how carbon can join to other carbon atoms in chains and rings to form large and complex molecules. **B1.2B** Recognize the six most common elements in organic molecules (C, H, N, O, P, S). **B1.2C** Describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids). **B1.2D** Explain the primary functions of the major complex organic molecules that compose living organisms. **Technical Vocabulary** Enzyme, organic, sugar, phosphate, carbohydrate, lipid, protein, nucleotide base ***Content Clarification:*** **Carbohydrates** are made of C, H, and O arranged in chains of glucose molecules. Carbohydrates provide and store energy.	***Content Statement*** **B1.2x Proteins** Proteins are composed mostly of amino acids and are made of C, H, O, and N, and function as enzymes, structural components, and hormones. ***Identifying and Using Performance Expectations*** **B1.2e** Explain the role of enzymes in biochemical reactions. **B1.2f** Describe how proteins control life functions (e.g., the proteins myosin and actin interact to cause muscular contraction; the protein hemoglobin carries oxygen in some organisms). **B1.2g** Propose how moving an organism to a new environment may influence it ability to survive and predict the possible impact of this type of transfer. ***Content Clarification*** **Enzymes** are proteins that catalyze chemical reactions in living systems. Enzymes function only in specific reactions and within narrow physical conditions. They speed reactions and allow them to proceed at lower temperatures.

Lipids serve as long term energy sources and as insulation and are made of C, H, and O arranged in long chains insoluble in water. **Proteins** may be structural or may function in transport, movement, defense, or cell regulation. Proteins are composed mostly of amino acids and are made of C, H, O, and N. **Nucleic acids** (DNA and RNA) are made of C, H, O, N, and P; they function as messengers and carry genetic information.	**Nucleic acids** are composed of a sugar, a phosphate, and a nucleotide base (made of C, H, O, N, and P); they function as messengers and carry genetic information.
Content Statement **B1.3 Maintaining Environmental Stability** The internal environment of living things must remain relatively constant. Many systems work together to maintain stability. Stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents. ***Identifying and Using Performance Expectations*** **B1.3A** Describe how cells function in a narrow range of physical conditions, such as temperature and pH (acidity), to perform life functions that help to maintain homeostasis. **B1.3B** Describe how the maintenance of a relatively stable internal environment is required for the continuation of life. **B1.3C** Explain how stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents. **Technical Vocabulary** Homeostasis, pH ***Content Clarification:*** Most organisms can tolerate small changes in pH. Most cells function best within a narrow range of temperature and pH. At very low temperatures, reaction rates are too slow. High temperatures or extremes of pH can change the structure or proteins and later their function.	***Content Statement*** **B1.3x Homeostasis** The internal environment of living things must remain relatively constant. Many systems work together to maintain homeostasis. When homeostasis is lost, death occurs. ***Identifying and Using Performance Expectations*** **B1.3d** Describe how organisms maintain a stable internal environment using the circulatory, endocrine, excretory, and immune response systems. **B1.3e** Describe how the human body maintains relatively constant internal conditions (temperature, acidity, and blood sugar). **B1.3f** Explain how human organ systems help maintain human health. **B1.3g** Compare the structure and function of a human body system or subsystem to a nonliving system (e.g., human joints to hinges, enzyme and substrate to interlocking puzzle pieces).
Content Statement **B1.4 Cell Specialization** In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of cells for food, air, and waste removal. The way in which cells function is similar in all living organisms. ***Identifying and Using Performance Expectations*** **B1.4A** Describe ways in which living things can be classified based on each organism's internal and external structure, their development, and relatedness of DNA sequence. **B1.4B** Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes. **B1.4C** Describe how various organisms have developed different specializations to accomplish a particular function and yet the end result is the same (e.g., excreting nitrogenous wastes in animals, obtaining oxygen for respiration). **B1.4D** Explain how different organisms accomplish the same result using different structural specializations (gills vs. lungs	***Content Statement*** **B1.4x Cell Specialization** In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of cells for food, air, and waste removal. The way in which cells function is similar in all living organisms. ***Identifying and Using Performance Expectations*** **B1.4e** Explain how cellular respiration is important for the production of ATP (build on aerobic vs. anaerobic). **B1.4f** Recognize and describe that both living and nonliving things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP. **B1.4g** Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.

vs. membranes). **Technical Vocabulary** ATP, cellular respiration, aerobic, anaerobic, prokaryote, eukaryote, endosymbiotic theory, mitochondrion, chloroplast, organelle?, potential energy ***Boundary Limit Expectations:*** All living things have similar requirements for life. Students should focus on the common functions of cells and organ systems that allow them to transform energy and carry out cellular functions. This standard does not address ancestral commonalities leading to evidence for evolution.	***Content Clarification:*** Modern cells have within them structures that may have existed as free-living cells. The mitochondria appear to be the descendants of bacteria as do the plastids in plant cells. The idea that organelles descended from free-standing bacteria is called the endosymbiotic theory. ***Content Clarification:*** Cellular respiration allows living things to transfer the energy they acquire into a form usable by the cell, ATP. ATP supplies the energy for most living things. It stores potential energy in its high energy phosphate-to-phosphate bonds.
Content Statement **B1.5 Living Organism Composition** All living or once living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates and lipids contain many carbon-hydrogen bonds that also store energy. ***Identifying and Using Performance Expectations*** **B1.5A** Recognize and explain that macromolecules such as lipids contain high energy bonds. **B1.5B** Explain how major systems and processes work together in animals and plants, including relationships between organelles, cells, tissues, organs, organ systems, organisms; relate to molecular functions. **B1.5C** Describe how energy is transferred and transformed from the Sun to energy-rich molecules during photosynthesis. **B1.5D** Describe how individual cells break down energy-rich molecules to provide energy for cell functions. **Technical Vocabulary** Diffusion, osmosis, active transport, protein synthesis, plasma/cell membrane ***Content Clarification:*** Prokaryotic cells do not have membrane-bound organelles and are therefore considered more primitive than eukaryotic cells. Eukaryotic have several organelles that carry out specialized functions. All multicellular organisms are composed of eukaryotic cells.	***Content Statement*** **B1.5x ATP** All living or once living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates and lipids contain many carbon-hydrogen bonds that also store energy. However, that energy must be transferred to ATP to be usable by the cell. ***Identifying and Using Performance Expectations*** **B1.5e** Explain the interrelated nature of photosynthesis and cellular respiration. **B1.5f** Relate plant structures and functions to the process of photosynthesis and respiration. **B1.5 g** Compare and contrast plant and animal cells. **B1.5 h** Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport). **B1.5i** Relate cell parts/organelles to their function. ***Content Clarification:*** Plant cells capture the energy of the sun in photosynthesis and store it for later use as carbohydrates. Through cellular respiration carbohydrates are broken down and energy is transferred to ATP where it is accessible for use by the cell. ***Content Clarification:*** Organelles are highly organized structures that are found in eukaryotic cells. Most are bound by membranes and contain specialized structures that allow them to carry out specific functions such as protein synthesis, packaging of cellular chemicals, and transfer of energy. *Content Clarification:* The plasma membrane surrounds the cell providing a protective, yet fluid barrier to the environment. Membrane structure allows for some molecules to move in and out of the cells.

	Content Statement **B1.6x Internal/External Cell Regulation** Cellular processes are regulated both internally and externally by environments in which cells exist, including local environments that lead to cell differentiation during the development of multicellular organisms. During the development of complex multicellular organisms, cell differentiation is regulated through the expression of different genes. **B1.6a** Describe how dehydration and hydrolysis relate to organic molecules. **B1.6b** Identify the general functions of the major systems of the human body (digestion, respiration, reproduction, circulation, excretion, protection from disease, and movement, control, and coordination) and describe ways that these systems interact with each other. **B1.6c** Explain that the regulatory and behavioral responses of an organism to external stimuli occur in order to maintain both short- and long-term equilibrium. **B1.6d** Explain that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Note that cell behavior can also be affected by molecules from other parts of the organism, such as hormones. **B1.6e** Recognize and explain that communication and/or interaction are required between cells to coordinate their diverse activities. **B1.6f** Explain how higher levels of organization result from specific complex interactions of smaller units and that their maintenance requires a constant input of energy as well as new material. **B1.6g** Analyze the body's response to medical interventions such as: organ transplants, medicines, and inoculations. **Technical Vocabulary** Cell differentiation, gene expression, cell cycle?, dehydration reaction, hydrolysis reaction, regulartory response, behavioral response, external stimulus, equilbirium
Inquiry, Reflection, and Technology Performances	
B1.R1 Discuss how microscopes, advanced microscopy, and other technologies have contributed to our knowledge of cell function and structure. **B1.R2** Design and conduct experiments that demonstrate how decomposers use dead material as growth medium. **B1.R3** Design an experiment and record results of transplanting cells in developing embryos. **B1.R4** Design and discuss results of an experiment that limits essential elements from the medium of developing cells. **B1.R5** Investigate and distinguish between prokaryotic cells and eukaryotic cells, in terms of their general structures and degrees of complexity.	**B1.r7** Identify a biological topic that was dependent upon technological advancements. Research that topic and engage in a discussion of the advantages that technology provided and the disadvantages of the use of technology. For example, chemotherapy has allowed patients with cancer to be cured; however it interferes with normal cell division and often causes much discomfort to the patient. Tissue culturing has been a tremendous advancement in the treatment of burn victims. Yet some people are opposed to it because it is not natural. **B1.r8** Describe technologies used in the prevention,

B1.R6 Illustrate how the modern cell theory exemplifies how scientific knowledge usually grows slowly, through contributions from many different investigators from diverse cultures.	diagnosis, and treatment of diseases and explain their functions in terns of human body processes. **B1.r9** Investigate how technology is used to improve the health of individuals. **B1.r10** Design, conduct, collect data, and analyze an experiment in which the homeostatic control of organisms is challenged (e.g., culture of bacteria or mold exposed to temperature extremes). **B1.r11** Design and experiment that demonstrates how enzyme function is influenced by environmental differences (temperature or pH). **B1.r12** Design an experiment to demonstrate that the organic compounds produced by plants are the primary source of energy and nutrients for most living things, using isotopes. **B1.r13** Design and conduct and experiments that would trace the movement of food materials from a food source to a structural component of another organism.

Standard B2 – Interdependence of Living Systems and the Environment

Standard Statement

Students describe the processes of photosynthesis and cellular respiration and how energy is transferred through food webs. They recognize and analyze the consequences of the dependence of organisms on environmental resources and the interdependence of organisms in ecosystems.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **L2.p1** *Prerequisite:* Organisms acquire their energy directly or indirectly from sunlight. Plants capture the sun's energy and turn it into food through the process of photosynthesis. Through the process of cellular respiration, animals are able to release the energy stored in the molecules produced by plants and use it for cellular processes. ***Identifying and Using Performance Expectations*** Draw an aquatic and terrestrial food web using arrows to show the flow of energy. Describe how organisms acquire energy directly or indirectly from sunlight. Draw a food web including humans.	***Identifying and Using Performance Expectations*** ▪ Illustrate and describe the energy conversions that occur during photosynthesis and respiration. ▪ Recognize the equations for photosynthesis and respiration and identify the reactants and products for both. ▪ Write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean. ▪ Summarize the process of photosynthesis including o cells trap energy from sunlight with chlorophyll, and use the energy, carbon dioxide, and water to produce energy-rich organic molecules and oxygen; o photosynthesis involves an energy conversion in which light energy is converted to chemical energy in specialized cells (e.g., plants and some protists).
Content Statement	

L2.p2 *Prerequisite:* Organisms of one species form a population. Populations of different organisms interact and form communities. Living communities and the nonliving factors that interact with them form ecosystems. ***Identifying and Using Performance Expectations*** ▪ Provide examples of a population, community, and ecosystem.	
Content Statement **L2.p3:** *Prerequisite* Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other. ***Identifying and Using Performance Expectations*** ▪ Describe common relationships among organisms and provide examples of producer/consumer, predator/prey, or parasite/host relationship. ▪ Describe common ecological relationships between and among species and their environments (competition, territory, carrying capacity, natural balance, population, dependence, survival, and other biotic and abiotic factors). ▪ Describe the role of decomposers in the transfer of energy in an ecosystem. ▪ Explain how two organisms can be mutually beneficial and how that can lead to interdependency. ▪	
Content Statement **L2.p4:** (*Prerequisite)* The number of organisms and populations an ecosystem can support depends on the biotic resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. ***Identifying and Using Performance Expectations*** Identify the factors in an ecosystem that influence fluctuations in population size. Distinguish between the living (biotic) and nonliving (abiotic) components of an ecosystem. Explain how biotic and abiotic factors cycle in an ecosystem (water, carbon, oxygen, and nitrogen). Predict how changes in one population might affect other populations based upon their relationships in a food web.	
Content Statement **L2.p5** *(Prerequisite)* All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organisms or other organisms, whereas others are beneficial. ***Identifying and Using Performance Expectations*** Recognize that and describe how human beings are part of Earth's ecosystems. Note that human activities can deliberately or inadvertently alter the equilibrium	

in ecosystems.	
Content Statement **B2.1 Ecosystems** The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in an ecosystem, some energy is stored in newly made structures, but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. ***Identifying and Using Performance Expectations*** **B2.1A** Identify where energy is stored in an ecosystem. **B2.1B** Describe energy transfer through an ecosystem accounting for energy lost to the environment as heat. **B2.1C** Draw the flow of energy through an ecosystem. Predict changes in the food web when one or more organisms are removed. **Technical Vocabulary** Heat, aquatic, terrestrial, chlorophyll, population, community, ecosystem	***Identifying and Using Performance Expectations*** **B2.1d** Describe how carbon and other nutrients cycle through an ecosystem.
Content Statement **B2.2 Element Recombination** As matter cycles and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change. ***Identifying and Using Performance Expectations*** **B2.2A** Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life. **B2.2B** Use a food web to identify and distinguish producers, consumers, and decomposers, and explain the transfer of energy through trophic levels. **B2.2C** Diagram and describe the stages of the life cycle for a human disease-causing organism. **Technical Vocabulary** Conservation of matter, conservation of energy, nutrient cycling, trophic level, food chain, food web, energy transfer, producer, consumer, predator, prey, parasite, decomposer, host, scavenge, competition, adaptation, dependence	
Content Statement **B2.3 Changes in Ecosystems** Although the interrelationships and interdependence of organisms may generate biological communities in ecosystems that are stable for hundreds or thousands of years, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution. The impact of the human species has major consequences for other species.	***Content Statement*** **B2.3x Human Impact** Humans can have tremendous impact on the environment. Sometimes their impact is beneficial and sometimes it is detrimental.

Identifying and Using Performance Expectations

B2.3A Describe ecosystem stability. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

B2.3B Recognize and describe that a great diversity of species increases the chance that at least some living organisms will survive in the face of large (cataclysmic?) changes in the environment.

B2.3c Examine the effects of human activities such as reducing the amount of forest cover, increasing the chemicals released into the atmosphere, and intensive farming have changed the Earth's land, oceans, and atmosphere and also its capacity to support life forms.

Technical Vocabulary
Migration, succession, greenhouse effect, global warming, species diversity, deforestation, pollution

Identifying and Using Performance Expectations

B2.3d Describe the greenhouse effect and list possible causes.
B2.3e List the possible consequences of global warming.

Content Statement

B2.4 Populations

Populations of living things increase and decrease in size as they interact with other populations and with the environment. The rate of change is dependent upon relative birth and death rates.

Identifying and Using Performance Expectations

B2.4A Graph changes in population growth given a data table.
B2.4B Explain the influences that affect population growth including those characteristic of the organism and environmental influences.
B2.4C Predict the consequences of an invading organism on the survival of other organisms.

Technical Vocabulary
Birth rate, death rate, carrying capacity, exponential growth

Content Statement

B2.4x Environmental Factors

Population growth occurs in different patterns as influenced by environmental factors. A very rapid increase in organisms occurs when environmental resources are not limited; as resources decrease, the rate of increase decreases until the population (usually) stabilizes at the carrying capacity for that geographical area.

Identifying and Using Performance Expectations

B2.4d Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.

B2.4e Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.

B2.4f Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.

Inquiry, Reflection, and Technology Performances

B2.R1 Analyze and graph changes in an ecosystem resulting from natural causes, changes in climate, human activity, technology, or introduction of non-native species. Use data to make predictions.
B2.R2 Predict the impact of human population growth on the environment and the survival of other organisms in given situations.
B2.R3 Locally, or in a larger geographical area such as the Great Lakes watershed, identify and describe an ecosystem, including

- effects of biotic and abiotic components
- examples of interdependence
- evidence of human influences
- energy flow and nutrient cycling
- diversity analysis
- ecological succession.

B2.r4 Apply the concepts of population dynamics to the human population and identify factors affecting changes in population size.

Standard B3: Genetics

Standard Statement

Students recognize that the specific genetic instructions for any organism are contained within genes composed of DNA molecules located in chromosomes. They explain the mechanism for the direct production of specific proteins based on inherited DNA. Students diagram how occasional modifications in genes and the random distribution of genes from each parent provide genetic variation and become the raw material for evolution. Content Statements, Performances, and Boundaries

Essential	**Core**
Content Statements, Identifying and Using Performances	
Content Statement **L3.p1** *Prerequisite:* Reproduction is a characteristic of all living systems**;** because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually. ***Identifying and Using Performance Expectations*** ▪ Compare and contrast the differences between sexual and asexual reproduction. ▪ Discuss the advantages and disadvantages of sexual vs. asexual reproduction. ▪ Explain how example organisms reproduce (e.g., bacteria, yeast, flowering plants, insects, birds, mammals)	
Content Statement **L3.p2** *Prerequisite:* The characteristics of organisms are influenced by heredity and environment. For some characteristics, inheritance is more important; and for other characteristics, interactions with the environment are more important. ***Identifying and Using Performance Expectations*** ▪ Explain that the traits of an individual are influenced by both the environment and the genetics of the individual. Acquired traits are not inherited. Only genetic traits are inherited.	
Content Statement **B3.1 Genetics and Inherited Traits** Hereditary information is contained in genes, located in the chromosomes of each cell. Cells contain many thousands of different genes. One or many genes can determine an inherited trait of an individual, and a single gene can influence more than one trait. Before a cell divides, this genetic information must be copied and apportioned evenly into the daughter cells.	***Identifying and Using Performance Expectations***

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Identifying and Using Performance Expectations

B3.1A Draw and label a heterozygous chromosome pair highlighting a particular gene location.
B3.1B Explain that the information passed from parents to offspring is transmitted by means of genes which are coded in DNA molecules. These genes contain the information for the production of proteins.
B3.1C Differentiate between dominant, recessive, codominant, polygenic, and sex-linked traits.
B3.1D Explain the genetic basis for Mendel's laws of segregation and independent assortment.
B3.1E Describe a specific example of a gene controlling a trait, (i.e., Sickle cell anemia, other).
B3.1F Determine the genotype and phenotype of monohybrid crosses using a Punnett Square.

Technical Vocabulary
Species, sexual reproduction, heredity, inheritance, trait (acquired/ inherited), gene, chromosome, heterozygous, homozygous, dominant, recessive, codominant, polygenic, sex-linked, segregation, independent assortment, genotype, phenotype, DNA sequence, Punnett square

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B3.1g Explain that the similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a unique species, different from all others. Likewise, understand that every other species has its own characteristic DNA sequence.
B3.1h Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules using virtually the same mechanism in all life forms.

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Content Statement

B3.2 DNA

The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.

Identifying and Using Performance Expectations

B3.2A Show that when mutations occur in sex cells, they can be passed on to offspring (inherited mutations), but if they occur in other cells, they can be passed on to descendant cells only (non-inherited mutations).
B3.2B Recognize that every species has its own characteristic DNA sequence.
B3.2C Describe the structure and function of DNA.
B3.2D Predict the consequences that changes in the DNA composition of particular genes may have on an organism.
B3.2E Propose possible effects (on the genes) of exposing an organism to radiation and toxic chemicals.

Technical Vocabulary
Mutation, DNA replication, transcription, translation, genetic engineering, recombinant DNA

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Identifying and Using Performance Expectations

B3.2f Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms.
B3.2g Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.
B3.2h Recognize that genetic engineering techniques provide great potential

B3.2i Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes.

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	Content Statement **B3.3x RNA & Protein Synthesis** Protein synthesis begins with the information in a sequence of DNA bases being copied onto messenger RNA. This molecule moves from the nucleus to the ribosome in the cytoplasm where it is "read." Transfer RNA brings amino acids to the ribosome where they are connected in the correct sequence to form a specific protein. ***Identifying and Using Performance Expectations*** **B3.3a** Describe the general pathway by which ribosomes synthesize proteins by using tRNAs to translate genetic information encoded in mRNAs. **Technical Vocabulary** Messenger RNA, nucleus, ribosome, transfer RNA, protein synthesis
Content Statement **B3.4 Sexual Reproduction** Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents. ***Identifying and Using Performance Expectations*** **B3.4A** Diagram the processes of cell division (mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations. **B3.4B** Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring. **B3.4C** Illustrate that the sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of two parents. **B3.4D** Differentiate between mitosis and meiosis in terms of both process and significance. **B3.4E** Explain how zygotes are produced in the fertilization process. **B3.4F** Explain how it might be possible to identify genetic defects from just a few cells of an embryo. **Technical Vocabulary** Cell division, mitosis, meiosis, gamete, genetic recombination, fertilization, zygote, embryo	***Identifying and Using Performance Expectations*** **B3.4g** Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes. **B3.4h** Predict how mutations will be transferred to progeny. **B3.4i** Explain that cellular differentiation results from gene expression and/or environmental influence.

	Content Statement **B3.5x Genetic Variation** Genetic variation is essential to biodiversity and the stability of a population. Genetic variation is ensured by the formation of gametes and their combination to form a zygote. Opportunities for genetic variation also occur during cell division when chromosomes exchange genetic material causing permanent changes in the DNA sequences of the chromosomes. Random mutations in DNA structure caused by the environment are another source of genetic variation. ***Identifying and Using Performance Expectations*** **B3.5a** Describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it, and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment. **B3.5b** Explain that gene mutation in a cell can result in uncontrolled cell division, called cancer. Also know that exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer. **B3.5c** Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and in its offspring. **Technical Vocabulary** Biodiversity, insertion, deletion, substitution, cancer
	Content Statement **B3.6x Recombinant DNA** Recombinant DNA technology allows scientists in the laboratory to combine the genes from different sources, sometimes different species, into a single DNA molecule. This manipulation of genes using bacterial plasmids has been used for many practical purposes including the mass production of chemicals and drugs. ***Identifying and Using Performance Expectations*** **B3.6a** Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. **B3.6b** Evaluate the advantages and disadvantages of human manipulation of DNA. **Technical Vocabulary** Recombinant DNA, bacterial plasmid
Inquiry, Reflection, and Technology Performances	
B3.R1 Conduct a family investigation of a particular gene trait; determine phenotype and predict genotypes of family members for three generations (i.e., tongue rolling, widow's peak, etc.) **B3.R2** Relate changes resulting from genetic engineering to real life. (B3.2)	**B3.r3** Design and conduct a simple dihybrid cross of two heterozygotes; use the results of the investigation to make reasonable inferences of how traits are inherited. **B3.r4** Predict the impact of genetic engineering on future products.

Standard B4: Evolution and Biodiversity

Standard Statement

Students recognize that evolution is the result of genetic changes that occur in constantly changing environments. They can explain that modern evolution includes both the concepts of common descent and natural selection. They illustrate how the consequences of natural selection and differential reproduction have led to the great biodiversity on Earth.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **L4.p1:** Individual organisms with certain traits in particular environments are more likely than others to survive and have offspring. When an environment changes, the advantage or disadvantage of characteristics can change. Extinction of a species occurs when the environment changes and the characteristics of a species are insufficient to allow survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the Earth no longer exist. *(Prerequisite)* ▪ Define a species, and give examples. ▪ Define a population, and identify local populations. ▪ Explain how extinction removes genes from the gene pool. ▪ Explain the importance of the fossil record.	
Content Statement **L4.p2:** Similarities among organisms are found in anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance. *(Prerequisite)* ***Identifying and Using Performance Expectations*** ▪ Explain, with examples, that ecology studies the varieties and interactions of living things across space while evolution studies the varieties and interactions of living things across time.	
Content Statement **B4.1 Theory of Evolution** The Theory of Evolution provides a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. ***Identifying and Using Performance Expectations*** **B4.1A** Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending upon environmental conditions). **B4.1B** Describe how natural selection provides a mechanism for	

evolution. **B4.1C** Summarize the relationships between present-day organisms and those that inhabited the Earth in the past (e.g., use fossil record, embryonic stages, homologous structures, chemical basis). **B4.1D** Explain how a new species or variety may originate through the evolutionary process of natural selection. **B4.1E** Explain how natural selection leads to organisms that are well suited for the environment (differential survival and reproduction of chance inherited variants, depending upon environmental conditions). **B4.1F** Explain using examples how the fossil record, comparative anatomy, and other evidence support the theory of evolution. **B4.1G** Illustrate how genetic variation is preserved or eliminated from a population through Darwinian natural selection (evolution) resulting in biodiversity. **Technical Vocabulary** Natural selection, differential survival, evolution, homologous structures, comparative anatomy	
Content Statement **B4.2 Molecular Evidence** Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descents branched. ***Identifying and Using Performance Expectations*** **B4.2A** Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular similarities. **B4.2B** Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA and protein sequences. **B4.2C** Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of sub-populations. **Technical Vocabulary** Morphologic similarities, genetic drift, sub-population, cladogram, phylogenetic tree ***Add link from MSTA web site - Greg Forbes.***	***Identifying and Using Performance Expectations*** **B4.2d** Interpret a cladogram or phylogenetic tree showing evolutionary relationships among organisms.
Content Statement **B4.3 Natural Selection** Evolution is the consequence of natural selection, the interactions of (1) the potential for a population to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection from environmental pressure of those organisms better able to survive and leave offspring. ***Identifying and Using Performance Expectations***	***Identifying and Using Performance Expectations***

<table>
<tr><td>B4.3A Explain how natural selection acts on individuals, but it is populations that evolve. Relate genetic mutations and genetic variety produced by sexual reproduction to diversity within a given population.
B4.3B Describe the structures of viruses and bacteria.
B4.3C Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells.
B4.3D Describe the role of geographic isolation in speciation.
B4.3E Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms.
B4.3F Explain how evolution through natural selection can result in changes in biodiversity through the increase or decrease of genetic diversity from a population.

Technical Vocabulary
Virus, bacteria, bacterial DNA, speciation

Note: Find a spot for classification of plant, animal, bacteria, viruses, other without dwelling on details of complete classification system.</td><td>B4.3g Explain how changes at the gene level are the foundation for changes in populations and eventually the formation of new species.
B4.3h Demonstrate and explain how biotechnology can improve a population and species.</td></tr>
<tr><th colspan="2">Inquiry, Reflection, and Technology Performances</th></tr>
<tr><td>B4.R1 Relate the extinction of species to a mismatch of adaptation and the environment.</td><td>B4.r2 Explain that DNA technologies allow scientists to identify, study, and modify genes. Forensic identification is one example of DNA technology.
B4.r3 Explain the common beliefs about heredity before Darwin’s Origin of Species, and the significance and success of this explanation of natural selection and heredity.
B4.r4 Explain how the rediscovery of Gregor Mendel’s genetics experiments supported the theory of biological evolution suggested by Charles Darwin.</td></tr>
<tr><td><u>Boundaries</u>

<u>Essential Technical Vocabulary</u>

▪ homozygous, heterozygous, monohybrid, dihybrid, recessive, dominant, codominant, polygenic, sex-linked traits, Punnett Square, DNA, RNA

<u>Essential Foundational Knowledge</u>

▪ basic computational skills, graphing, ratios, basic scientific design, hypothesis, theory.
show first bullet as essential across discipline
▪ reproductive process, how DNA and genes are transferred from one generation to the next (mitosis, meiosis)</td><td></td></tr>
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Michigan High School Science

PHYSICS

Prerequisite, Essential, and Core

Content Statements and Expectations

C E • **R I G O R** • R E L E V A N C E • R E L A T I O N S H I P S • R I G O R • R E
I P S • R E L A T I O N S H I P S • R I G O R • **R E L E V A N C E** • R E L A T
C E • R I G O R • R E L E V A N C E • R E L A T I O N S H I P S • R I G O R • R E
I P S • **R E L A T I O N S H I P S** • R I G O R • R E L E V A N C E • R E L A T

MICHIGAN Department of Education

PHYSICS (P)

Physics is a basic science. It is a human construct to attempt to explain observations on both the macro and micro levels. Knowledge of physical principles allows understanding in other sciences and everyday experiences, (e.g. heat exchanges in the atmosphere as they relate to weather; pressure and temperature differences causing different geological formations; radiation of electromagnetic energy and how it affects photosynthesis; the behavior of light and the eye; electricity, electromagnetic waves and your cell phone; nuclear fission and power plants; atomic structure and chemical reactions; etc.)

Energy is a constant in an ever-changing world. Energy from the sun fuels electrical storms, hurricanes, tornados, and photosynthesis. In turn, the products of photosynthesis (carbohydrates and oxygen) react during respiration to fuel the life processes, such as growth and reproduction, of plants and animals. Energy is the conceptual system for explaining how the universe works and accounting for changes in matter. (NAEP) Energy is not a "thing". "Three energy-related ideas are important. One is energy transformation. All physical events involve transferring energy or changing one form of energy into another. … A second idea is the conservation of energy. … A third idea is that whenever there is a transformation of energy, some of it is likely to go into heat which is spread around and is therefore not available for use." (*Benchmarks for Science Literacy*, AAAS, 1993)

The universe is in a state of constant change. From smallest particles (electrons) to the largest systems (galaxies) all things are in motion. Therefore, understanding the universe requires the ability to describe and represent various types of motion. Kinematics, the description of motion, always involves measurements of position and time. The relationships between these quantities can be represented by mathematical statements, graphs, and motion maps. These representations are powerful tools that can not only describe past motions but can also predict future events.

Objects can interact with each other by direct contact (pushes or pulls, friction, etc.) or at a distance (gravity, electromagnetism, etc.). Forces are used for describing interactions between objects. Non-zero net forces always cause changes in motion (Newton's first law). These changes can be changes in speed, direction, or both. Newton's second law summarizes relationships between net forces, masses, and changes in motion. Whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted back on it (Newton's third law).

Outline of Physics Expectations

Standard P1: Forms of Energy and Energy Transformations

P1.1	Energy Transfer
P1.2	Energy Transformation
P1.3x	Work
P1.4	Kinetic and Potential Energy
P1.5x	Kinetic Energy Calculations
P1.6	Kinetic/Potential Energy Conversion
P1.7	Waves — Description
P1.8x	Waves — Characteristics
P1.9	Mechanical Wave Propagation
P1.10	Electromagnetic Waves
P1.11x	Diffraction and Interference
P1.12	Light
P1.13x	Reflection and Refraction
P1.14x	Wave-Particle Duality
P1.15	Electricity
P1.16	Circuits
P1.17x	Current and Power
P1.18x	Electromagnetic Propagation
P1.19x	Quantum Theory
P1.20	Heat
P1.21	Temperature
P1.22x	Energy Efficiency
P1.23	Nuclear Reactions
P1.24x	Mass and Energy

Standard P2: Motion of Objects

P2.1	Position -Time
P2.2	Velocity-Time
P2.3x	Frames of Reference

Standard P3: Forces and Motion

P3.1	Forces
P3.2	Net Forces
P3.3	Newton's Third Law
P3.4	Forces and Acceleration
P3.5x	Momentum
P3.6	Gravity
P3.7	Electric Charges and Coulomb's Law
P3.8x	Electromagnetic Force
P3.9	Forces — Strengths
P3.10x	Electrical Induction

Standard P1: Forms of Energy and Energy Transformations

Standard Statement

Energy is a useful conceptual system for explaining how the universe works and accounting for changes in matter. Energy is not a "thing." Students need to develop several energy-related ideas: First, they should be able to keep track of energy during transfers and transformations, and account for changes using energy conservation. Second, they should be able to identify places where energy is apparently lost during a transformation process, but is actually spread around to the environment as low grade thermal energy and therefore not easily recoverable. Third, they should be able to identify the means of energy transfers: collisions between particles, or waves.

Content Statements, Performances, and Boundaries

Content Statements	
Essential	**Core**
Content Statement **P1.1 Energy Transfer** Moving objects and waves transfer energy from one location to another. They also transfer energy to objects during interactions (e.g. sunlight transfers energy to the ground when it warms the ground; sunlight also transfers energy from the sun to the Earth.) ***Identifying and Using Performance Expectations*** **P1.1A** Account for and represent energy into and out of systems using energy transfer diagrams. **P1.1B** Explain instances of energy transfer by waves and objects in everyday activities (e.g. why the ground gets warm during the day, how you hear a distant sound, why it hurts when you get hit by a baseball, etc.)	

Content Statement **P1.2 Energy Transformation** Energy is often transformed from one form to another during changes in matter. The amount of energy before a transformation is equal to the amount of energy after the transformation. ***Identifying and Using Performance Expectations*** **P1.2A** Account for and represent energy transfer and transformation in complex processes (interactions) using energy transfer diagrams. **P1.2B** Name devices that transform specific types of energy into other types (e.g. a device that transforms electricity into motion, etc.) **P1.2C** Explain how energy is conserved in common systems (e.g., light incident on a transparent material, light incident on a leaf, mechanical energy in a collision, etc.) **P1.2D** Explain why all the stored energy in gasoline does not transform to mechanical energy of a vehicle. **Technical Vocabulary:** onservation of Energy, Transfer/transform	***Identifying and Using Performance Expectations*** **P1.2e** Explain the energy transformation as a skydiver falls at a steady velocity. **P1.2f** Identify and label the energy inputs, transformations, and outputs using qualitative or quantitative representations in simple technological systems (e.g. toaster, motor, hair dryer, etc.) to show energy conservation.
	Content Statement **P1.3x Work** Work is the amount of energy transferred during an interaction. In mechanical systems work is the amount of energy transferred as an object is moved through a distance: W = F d, where d is in the same direction as F. In electrical systems, work is done when charges move. ***Identifying and Using Performance Expectations*** **P1.3a** Calculate the amount of work done on an object (of mass m) that is moved from one position to another. **P1.1b** Using the formula for work, derive a formula for change in potential energy of an object lifted a distance h. **P1.3c** Calculate the amount of work done when a charge moves through a potential difference, V. **Technical Vocabulary:** Work
Content Statement **P1.4 Kinetic and Potential Energy** Moving objects have kinetic energy. Objects may have potential energy due to their relative positions (e.g., lifting an object or stretching a spring, energy stored in chemical bonds). ***Identifying and Using Performance Expectations*** **P1.4A** Identify the form of energy in given situations (e.g. moving objects, stretched springs, rocks on cliffs, energy in	

food, etc.) **Technical Vocabulary:** Kinetic Energy, Potential Energy	
	Content Statement **P1.5x Kinetic Energy Calculations** The kinetic energy of an object is related to the mass of an object and its speed: $KE = ½ m v^2$. ***Identifying and Using Performance Expectations*** **P1.5a** Rank the amount of kinetic energy from highest to lowest of everyday examples of moving objects.
Content Statement **P1.6 Kinetic/Potential Energy Conversion** Conversions between kinetic and gravitational potential energy are common in moving objects. In frictionless systems, the decrease in gravitational potential energy is equal to the increase in kinetic energy, or vice versa. ***Identifying and Using Performance Expectations*** **P1.6A** Describe the transformation of energy in simple mechanical systems, e.g. pendulums, roller coasters, ski lifts, etc. **P1.6B** Explain why all mechanical systems require an external energy source to maintain their motion.	***Identifying and Using Performance Expectations*** **P1.6c** Calculate the changes in kinetic and potential energy in simple mechanical systems (e.g. pendulums, roller coasters, ski lifts, etc.) using the formulas for kinetic energy and potential energy. **P1.6d** Calculate the impact speed (ignoring air resistance) of an object dropped from a specific height, or the maximum height reached by an object (ignoring air resistance) given the initial vertical velocity.
Content Statement **P1.7 Waves Description** Waves (mechanical and electromagnetic) are described by their wavelength, amplitude, frequency, and speed. ***Identifying and Using Performance Expectations*** **P1.7A** Describe specific mechanical waves (e.g., on a slinky, on the ocean, etc.) in terms of wavelength, amplitude, frequency, and speed. **P1.7B** Identify everyday examples of transverse and compression (longitudinal) waves. **P1.7C** Compare and contrast transverse and compression (longitudinal) waves in terms of wavelength, amplitude, and frequency.	

Technical Vocabulary: Slinky, transverse and longitudinal waves, wavelength, amplitude, frequency, wave velocity.	
	Content Statement **P1.8x Waves Characteristics** Wave velocity, wavelength, and frequency are related by $v = f \lambda$. The energy transferred by a wave is proportional to the square of the amplitude of vibration and its frequency. ***Identifying and Using Performance Expectations*** **P1.18a** Demonstrate that frequency and wavelength of a wave are inversely proportional in a given medium. **P1.18b** Compare the amount of energy transferred by transverse or compression waves of different amplitudes and frequencies (e.g. seismic waves, etc.) **Technical Vocabulary:** Inversely proportional

Content Statement

P1.9 Mechanical Wave Propagation

Vibrations in matter initiate mechanical waves (e.g., water waves, sound waves, seismic waves), which propagate in all directions and decrease in intensity in proportion to the distance squared. Waves transfer energy from one place to another without transferring mass.

Identifying and Using Performance Expectations

P1.9A Identify everyday examples of energy transfer by waves and their sources.

P1.9B Explain why a fishing bobber (for example) does not move forward as a wave passes under it.

P1.9C Provide evidence to support the claim that sound is energy transferred by a wave, not energy transferred by particles.

P1.9D Explain how waves propagate from vibrating sources and why the intensity decreases with the square of the distance from the source.

P1.9E Explain why everyone in a classroom can hear one person speaking, but why in the rear of a large concert auditorium an amplification system is necessary.

Technical Vocabulary:

Mechanical Waves (water waves, sound waves, seismic waves, waves on a string).

Content Statement

P1.10 Electromagnetic Waves

Electromagnetic waves (e.g., radio, microwave, infrared, visible light, ultraviolet, X-ray) are produced by accelerated charges or changing magnetic fields. Electromagnetic waves can travel through matter but they do not require a material medium (that is, they also travel through empty space). All electromagnetic waves move in a vacuum at the speed of light. Types of electromagnetic radiation are distinguished from each other by their wavelength and energy.

Identifying and Using Performance Expectations

P1.10A Identify the different regions on the electromagnetic spectrum and compare them in terms of wavelength, frequency, and energy.

P1.10B Explain why radio waves can travel through space, while sound waves cannot.

P1.10C Explain why there is a time delay between when we send a radio message to astronauts on the moon and when they receive it.

P1.10D Explain why we see a distant event before we hear it (e.g. lightning before thunder, exploding fireworks before the boom, etc.).

Identifying and Using Performance Expectations

P1.10e Explain why antennas are needed for radio, television and cell phone transmission and reception.

Technical Vocabulary: Electromagnetic Waves (x-ray, ultraviolet, infra red, radio, microwaves, visible light)	
	Content Statement **P1.11x Diffraction and Interference** Waves can bend around objects (diffraction). They also superimpose on each other and continue their propagation without a change in their original properties (interference). ***Identifying and Using Performance Expectations*** **P1.11a** Describe how two wave pulses propagated from opposite ends of a slinky interact as they meet. **P1.11b** List and analyze everyday examples that demonstrate the interference characteristics of waves (e.g. dead spots in an auditorium, whispering galleries, colors in a CD, beetle wings, etc.). **Technical Vocabulary:** Superimpose, diffraction, interference

Content Statement **P1.12 Light** Light interacts with matter as a wave, that is, it is reflected, absorbed or transmitted. ***Identifying and Using Performance Expectations*** **P1.12A** Identify the principle involved when you see a transparent object (e.g. straw, piece of glass, etc.) in a clear liquid. **P1.12B** Explain how various materials reflect, absorb or transmit light in different ways. **P1.12C** Explain why the sun appears reddish and larger at sunrise and sunset. **Technical Vocabulary:** Reflection, absorption, refraction, transmission	
	Content Statement **P1.13x Reflection and Refraction** The laws of reflection and refraction quantify the relationships between incident and reflected/refracted waves. ***Identifying and Using Performance Expectations*** **P1.13a** Draw ray diagrams to indicate how light reflect off objects or refracts into transparent media. **P1.13b** Predict the path of reflected light from flat, curved, or rough surfaces (e.g. flat and curved mirrors, painted walls, paper, etc.). **P1.13c** Given an angle of incidence and indices of refraction of two materials, calculate the path of a light ray incident on the boundary. **P1.13d** Explain how microscopes, telescopes, binoculars and magnifying glasses work. **Technical Vocabulary:** Angle of incidence, angle of reflection, angle of refraction, index of refraction
	Content Statement **P1.14x Wave Particle Duality** The dual wave-particle nature of matter and energy is the foundation for modern physics. ***Identifying and Using Performance Expectations*** **P1.14a** Describe evidence that supports the dual wave - particle nature of energy.

Content Statement

P1.15 Electricity

Electricity is a particularly useful form of energy because it can be easily transferred from place to place, and readily transformed by various devices into other forms of energy (e.g., light, heat, sound, and motion).

Identifying and Using Performance Expectations

P1.15A Describe the energy transformations when electrical energy is produced and transferred to homes and businesses.

P1.15B Identify common household devices that transform electrical energy to other forms of energy, and describe the type of energy transformation.

Content Statement

P1.16 Circuits

Electricity is described as movement of charges (current) in a circuit, the potential difference (voltage) of the power source, and the resistance of the loads in the circuit.

Identifying and Using Performance Expectations

P1.16A Given diagrams of many different possible connections of electric circuit elements, identify complete circuits, open circuits, short circuits, and explain the reasons for the classification.

P1.16B Discriminate between voltage, resistance, and current as they apply to an electric circuit.

Technical Vocabulary:

Current, potential difference, resistance

	Content Statement **P1.17x Current and Power** In circuits, the relationship between electric current, I, electric potential difference, V, and resistance, R, is quantified by V= I R. Electric power is the amount of work done by an electric current in a unit time, which can be calculated using P= I V. ***Identifying and Using Performance Expectations*** **P1.17a** Explain energy transfer in a circuit, using an electrical charge model. **P1.17b** Compare the currents, voltages and power in parallel and series circuits. **P1.17c** Explain how circuit breakers and fuses protect household appliances. **P1.17d** Compare the energy used in one day by common household appliances (e.g. refrigerator, lamps, hair dryer, toaster, televisions, music players, etc.). **P1.17e** Explain the difference between electric power and electric energy as used in bills from an electric company. **Technical Vocabulary:** Power
	Content Statement **P1.18x Electromagnetic Propagation** Modulated electromagnetic waves can transfer information from one place to another, (e. g., televisions, radios, telephones, computers and other information technology devices.) Digital communication makes more efficient use of the limited electromagnetic spectrum, is more accurate than analog transmission, and can be encrypted to provide privacy and security. ***Identifying and Using Performance Expectations*** **P1.18a** Explain how radio and television programs and cell phone conversations are transmitted and received. **P1.18b** Explain how different cell phone conversations can take place without interfering with other cell phone calls.

	Content Statement **P1.19x Quantum Theory** Electromagnetic energy is transferred in discrete amounts called quanta. The equation: $E= h f$ quantifies the relationship between the energy transferred and the frequency, where h is Planck's constant. ***Identifying and Using Performance Expectations*** **P1.19a** Calculate and compare the energy in various electromagnetic quanta, (e.g. visible light, x-rays, etc.) **P1.19b** Explain the relationship between the frequency of an electromagnetic wave and its technological uses. **Technical Vocabulary:** Quanta, Planck's constant
Content Statement **P1.20 Heat** Heat is the transfer of thermal energy between objects due to a temperature difference. Thermal energy transfers by conduction, convection, and radiation. ***Identifying and Using Performance Expectations*** **P1.20A** Compare and contrast conduction, convection and radiation as means of transferring thermal energy. **P1.20B** Describe how one object at a higher temperature in contact with another object transfers energy to that object at a lower temperature. **Technical Vocabulary:** Thermal energy, conduction, convection, radiation	
Content Statement **P1.21 Temperature** Thermal energy is the total internal kinetic energy of the atoms and/or molecules in an object. Temperature is a measure of the average kinetic energy of the atoms and/or molecules in an object. ***Identifying and Using Performance Expectation*** **P1.21A** Explain why a bathtub full of lukewarm water has more thermal energy than a tea cup filled with extremely hot water. **P1.21B** Predict the change in temperature of two liquids (same or different materials), at the same or different temperatures and masses that are combined. **Technical Vocabulary:** Temperature, heat	***Identifying and Using Performance Expectations*** **P1.21c** Propose a formula that predicts the final temperature of two liquids (same or different materials), at the same or different temperatures and masses that are combined.

	Content Statement **P1.22x Energy Efficiency** Heat is often produced as a by-product during energy transformations. This energy is transferred into the surroundings and is not usually recoverable. The efficiency of natural and man-made systems varies due to the amount of heat that is not recovered as useful work. ***Identifying and Using Performance Expectations*** **P1.22a** Calculate the energy lost to surroundings when you heat 40 gallons of water 20 Celsius degrees given the efficiency of a home hot water heater.
Content Statement **P1.23 Nuclear Reactions** Nuclear reactions (fission, fusion, and radioactive decay) can convert small amounts of matter into large amounts of energy. Fusion occurs spontaneously in the sun. Radioactive decay occurs spontaneously in the Earth's crust (rocks, minerals) and can be induced for use in technological applications (e.g. medical diagnosis and treatment) ***Identifying and Using Performance Expectations*** **P1.23A** Describe peaceful technological applications of nuclear fission and radioactive decay. **P1.23B** Describe possible problems caused by exposure to prolonged radioactive decay **P1.23C** Explain how stars including our sun produce huge amounts of energy (e.g. visible light, infrared, ultraviolet, etc.). **Technical Vocabulary:** Fission, fusion, radioactive decay	
	Content Statement **P1.24x Mass and Energy** In nuclear reactions a small amount of mass is converted to a large amount of energy: $E = mc^2$, where c is the speed of light in a vacuum. The amount of energy before and after nuclear reactions must consider mass changes as part of the energy transformation. **Identifying and Using Performance Expectation** **P1.24a** Explain where the light and thermal energy come from during fission and fusion nuclear reactions.

Inquiry, Reflecting, and Technology Performances

Essential: Inquiry and Technology	**Core: Inquiry and Technology**
P1.R1 Design a demonstration to show that energy is transferred in a collision between two objects. **P1.R2** Investigate the relationship between the amount of	**P1.r9** Investigate the relationships between the speed and frequency of a wave and the amount of stretch applied to a slinky.

energy transferred and the amplitude of the pulse using a slinky. **P1.R3** Investigate the relationship between the amount of energy transferred and the frequency of a wave using a slinky. **P1.R4** Support the concept that sound energy is transferred by waves using everyday evidence. **P1.R5** Predict and verify changes in the absorption, reflection, and transmission of light using clear transparent sheets (e.g. an overhead transparency) and a light source. **P1.R6** Investigate and compare the magnitude of current at various points in simple dc circuits using an ammeter and the circuits. **P1.R7** Design an investigation to demonstrate that our bodies are not reliable instruments to measure temperature differences. **P1.R8** Identify and compare the pros and cons of using fossil fuels and nuclear reactors in electrical power plants.	**P1.r10** Demonstrate the inverse square relationship between intensity of light and the distance from the source. **P1.r11** Design and critique investigations that could demonstrate the relationships between kinetic energy transfer and mass and velocity in collisions. **P1.r12** Demonstrate and explain, using a ripple tank or computer simulation program, the diffraction of waves around a barrier. **P1.r13** Support the theory that light energy is transferred as a wave using Young's double slit experiment. **P1.r14** Discuss the dilemma of explaining the photoelectric effect using only the wave behavior of light. **P1.r15** Analyze the problem, using historical references, that led Planck to propose the solution as a direct relationship between energy and frequency. **P1.r16** Design an experiment to compare the total electrical energy from a battery to the energy from burning a nut. **P1.r17** Propose various ways to reduce heat losses from and in your home. Explain how each way decreases the loss and estimate their relative (high, medium, and low) cost/benefit ratio.

Boundaries	
Essential examples or observations roller coasters, pendulum clocks, water waves, sound waves, nuclear reactors, interior of sun, atomic and thermonuclear reactions,	**Core examples or observations** ski lifts, ripple tanks, fuses, circuit breakers, water heater, power plants,
Essential instruments and units of measure Qualitative descriptions of physical properties: conductivity of heat and electricity, joules, degrees	**Core instruments and units of measure** drawing compass, light sources (boxes), optical bench, lenses, mirrors, thermometers, calories**,**
Essential representations Energy transfer diagrams, graphs and tables	**Core representations** computer simulations,

Standard P2: Motion of Objects

Standard Statement

The universe is in a state of constant change. From smallest particles (electrons) to the largest systems (galaxies) all things are in motion. Therefore, for students to understand the universe they must describe and represent various types of motion. Kinematics, the description of motion, always involves measurements of position and time. Students must describe the relationships between these quantities using mathematical statements, graphs, and motion maps. They need to use these representations as powerful tools to not only describe past motions but also predict future events.

Content Statements, Performance Expectations, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances, and Boundaries	
Content statement **P2.1 Position-Time** An object's position can be measured and graphed as a function of time. An object's speed can be calculated and graphed as a function of time. ***Identifying and Using Performance expectations*** **P2.1A:** Calculate the average speed of an object using the change of position and elapsed time. **P2.1B:** Represent the velocities for linear and circular motion using motion maps (arrows on strobe pictures). **P2.1C:** Create line graphs using measured values of position and elapsed time. **P2.1D:** Describe and analyze the motion that a position-time graph represents given the graph. **P2.1E:** Describe and classify various motions in a plane as one-dimensional, two dimensional, circular or periodic. **P2.1F:** Distinguish between rotation and revolution and describe and contrast the two speeds of an object like the earth. **Technical vocabulary:** Displacement, distance, elapsed time, speed, velocity, motion map, strobe picture, average acceleration, rotation, revolution, periodic, average (uniform) motion, circular motion, projectile. **Essential examples or observations:** Constant motion battery powered vehicles, bicycles, toys, and amusement park rides. **Essential instruments and units of measure** Quantitative measures of linear distance and times using standard laboratory instruments, such as rulers and stop watches. **Essential representations** Data tables, graphs, formulas, and motion maps **Boundary limit examples:** It is not expected that students will use kinematic expressions other than the definition of average acceleration to solve constant acceleration problems. It is not expected that students will use vector notations for variables in formulas.	***Identifying and Using Performance expectations*** **P2.1g:** Solve problems involving average speed and constant acceleration in one dimension. **P2.1h:** Analyze the changes in speed and direction in everyday examples of circular (rotation and revolution), periodic, and projectile motions. **Technical vocabulary:** Simple harmonic, reference frame, range, elevation. **Advanced examples or observations:** Projectiles in sports and history, amusement park rides, computer simulations, dragsters, astronomy **Advanced instruments and units of measure** Quantitative measures of linear distance and times using advanced laboratory instruments, such as range finders or gates. **Advanced representations** Computer generated graphs **Boundary limit examples:** It is not expected that students will solve kinematic problems involving situations where the acceleration is changing in magnitude. It is not expected that students will use Kepler's laws or conservation of energy to describe planetary motion. It is not expected that students will describe and compare the motion of an object using accelerated reference frames.
Content Statement **P2.2 Velocity-Time** The motion of an object can be described by its position and velocity as functions of time, and by its average speed	

and average acceleration during intervals of time.

Identifying and Using Performance expectations

P2.2A: Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.

P2.2B: Use the change of speed and elapsed time to calculate the average acceleration for linear motion.

P2.2C: Describe and analyze the motion that a velocity-time graph represents, given the graph.

P2.2D: Use the area under a velocity-time graph the calculate the distance traveled and the slope to calculate the acceleration.

P2.2E: State that uniform circular motion involves acceleration without a change in speed.

P2.2F: Describe the relationship between changes in position, velocity, and acceleration during periodic motion.

Essential technical vocabulary:

Displacement, distance, elapsed time, speed, velocity, motion map, strobe picture, average acceleration, rotation, revolution, periodic, average (uniform) motion, circular motion, projectile.

Essential examples or observations:

Constant motion battery powered vehicles, bicycles, toys, and amusement park rides.

Essential instruments and units of measure

Quantitative measures of linear distance and times using standard laboratory instruments, such as rulers and stop watches.

Essential representations

Data tables, graphs, formulas, and motion maps

Boundary limit examples:

It is not expected that students will use kinematic expressions other than the definition of average acceleration to solve constant acceleration problems.

It is not expected that students will use vector notations for variables in formulas.

Identifying and Using Performance expectations

P2.2g: Describe the independence of the vertical and horizontal motion components of a projectile.

P2.2h: Solve projectile motion problems with horizontal initial velocity.

P2.2i: Describe and explain planetary motion as a more general case of uniform circular motion involving acceleration.

P2.2j: Describe and classify various examples of periodic motion as simple harmonic(spring) or non-simple harmonic (bouncing ball).

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Content statement

P2.3 Frames of Reference

All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion.

Identifying and Using Performance Expectations

P2.3a: Describe and compare the motion of an object using different reference frames

Technical vocabulary:

Displacement, distance, elapsed time, speed, velocity,

	motion map, strobe picture, average acceleration, rotation, revolution, periodic, average (uniform) motion, circular motion, projectile. **Examples or observations:** Constant motion battery powered vehicles, bicycles, toys, and amusement park rides. **Instruments and units of measure** Quantitative measures of linear distance and times using standard laboratory instruments, such as rulers and stop watches. **Representations** Data tables, graphs, formulas, and motion maps **Boundary limit examples:** It is not expected that students will use kinematic expressions other than the definition of average acceleration to solve constant acceleration problems. It is not expected that students will use vector notations for variables in formulas.
Inquiry, Reflecting, and Technology Performances	
P2.R1 Design procedures to compare and investigate the average speed of different common moving objects using distance and time measuring tools. **P2.R2** Propose and critique the design of different methods of determining the height of a vertically launched projectile before and after the actual investigations.	**P2.r3** Use computer and probe technology to collect, graph, and analyze the motion of an object. **P2.r4** Describe the impact of uncertainty in measuring instruments on calculations of average speed and acceleration. **P2.r5** Design and perform an experiment to investigate the relationship between the range of a projectile and elevation of its launcher.

Standard P3: Forces and Motion

Standard Statement

Students should be able to identify interactions between objects either as being by direct contact (pushes or pulls, friction, etc.) or at a distance (gravity, electromagnetism, etc.), and to use forces to describe interactions between objects. Students should recognize that non-zero net forces always cause changes in motion (Newton's first law). These changes can be changes in speed, direction, or both. Students should be able to use Newton's second law to summarize relationships between net forces, masses, and changes in motion. Students should be able to explain that whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted back on it (Newton's third law).

Content Statements, Performance Expectations, and Boundaries

Essential	Core

Content Statements, Identifying and Using Performances, and Boundaries	
Content Statement **P3.1 Forces** Objects can interact with each other by direct contact (pushes or pulls, friction, etc.) or at a distance (gravity, electromagnetism, etc.). ***Identifying and Using Performance Expectations*** **P3.1A:** Classify interactions between objects as by direct contact or at a distance. **Technical Vocabulary:** Inertia	
Content Statement **P3.2 Net Forces** Forces have magnitude and direction. The net force on an object is the sum of all the forces acting on the object. Objects change their speed and/or direction only when a net force is applied. ***Identifying and Using Performance Expectations*** **P3.2A:** Identify the magnitude and direction of everyday forces (e.g. wind, tension in ropes, pushes and pulls, weight, etc.). **Technical Vocabulary:** Acceleration, net force	***Identifying and Using Performance Expectations*** **P3.2b:** Calculate all the forces on an object lying on an incline plane and describe the object's motion based on the forces.
Content Statement **P3.3 Newton's Third Law** Whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted back on it (Newton's third law). **Identifying and Using Performance expectation** **P3.3A:** Identify the action and reaction force from examples of forces in everyday situations (e.g. book on a table, walking across the floor, pushing open a door, etc.) **Technical Vocabulary:** Newton's three laws of motion	**Identifying and Using Performance expectations** **P3.3b:** Predict how the change in velocity of a small mass compares to the change in velocity of a large mass when the objects interact (e.g. collide). **P3.3c:** Explain the recoil of a projectile launcher in terms of forces and masses. **P3.3d:** Analyze why seat belts may be more important in autos than in buses.

Content Statement **P3.4 Forces and Acceleration** The change of speed and/or direction (acceleration) of an object is proportional to the net force and inversely proportional to the mass of the object. The acceleration and net force are always in the same direction. ***Identifying and Using Performance Expectations*** **P3.4A:** Predict the change in motion of an object acted on by several forces. **P34B:** Identify forces acting on objects moving with constant velocity, (e.g., cars on the highway). **P3.4C:** Solve problems involving force, mass, and acceleration in linear motion. **P3.4D:** Identify the forces acting on objects moving with uniform circular motion (e.g., satellites in orbit). **Technical Vocabulary:** Contact interactions, non-contact interactions **Boundary Limit:** It is not expected that students will analyze situations involving non-constant accelerations It is not expected that students will analyze situations involving more than four forces acting on an object It is not expected that students will analyze forces in three dimensions	***Identifying and Using Performance Expectations*** **P3.4e:** Solve problems involving force, mass, and acceleration in two-dimensional projectile motion restricted to an initial horizontal velocity. **P3.4f:** Calculate the changes in velocity of a thrown or hit object during and after the time it's acted on by the force. **P3.4g:** Explain how the time of impact can affect the net force (e.g., air bags in cars, catching a ball). **Boundary Limit:** It is not expected that students will analyze forces in three dimensions. It is not expected that students will analyze systems with changing mass.
	Content Statement **P3.5 Momentum** A moving object has a quantity of motion (momentum) that depends on its velocity and mass. In interactions between objects, the total momentum of the objects does not change. **Identifying and Using Performance expectations** **P3.5a:** Apply conservation of momentum to solve simple collision problems. **Technical Vocabulary:** Momentum, conservation of momentum

Content Statement **P3.6 Gravity** Gravitation is an attractive force that a mass exerts on every other mass. The strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. ***Identifying and Using Performance Expectations*** **P3.6A** Explain earth--moon interactions (orbital motion, tides) in terms of forces. **P3.6B** Predict how the gravitational force between objects changes when the distance between them changes. **P3.6C** Explain how your weight could be different from your earth weight on a different planet.	***Identifying and Using Performance Expectations*** **P3.6d** Calculate force, masses, or distance, given any three of these quantities by applying the Law of Gravity. **P3.6e** Draw arrows to represent how the force changes on an object in an elliptical orbit (direction and amount).
Content Statement ***P3.7 Electric Charges and Coulomb's Law*** Electric force exists between any two charged objects. Oppositely charged objects attract while objects with like charge repel. The strength of the electric force between two charged objects is proportional to the magnitudes of the charges and inversely proportional to the square of the distance between them. ***Identifying and Using Performance Expectations*** **P3.7A:** Predict how the electric force between charged objects varies when the distance between them and/or the magnitude of charges change. **P3.7B:** Explain why acquiring a large excess static charge (pulling off a wool cap, touching a Van de Graaff generator, combing) affects your hair.	***Identifying and Using Performance Expectations*** **P3.7c:** Determine the new electric force on charged objects after they touch and are then are separated. **P3.7d:** Propose a mechanism based on electric forces to explain current flow in an electric circuit. **Technical Vocabulary:** Electrostatic induction
	Content Statement **P3.8 Electromagnetic Force** Magnetic and electric forces are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces and moving magnets produce electric forces (e.g. electric current in a conductor). **Identifying and Using Performance expectation** **P3.8a:** Explain how the interaction of electric and magnetic forces is the basis for electric motors, generators, and the production of electromagnetic waves. **Technical Vocabulary:** Electromagnetism, electromagnetic induction, polarization

Content Statement **P3.9 Forces - Strengths** Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces (e.g., those exerted by a coiled spring or friction) may be traced to electric forces acting between atoms and molecules. **Identifying and Using Performance expectations** **P3.9A:** Explain why scientists can ignore the gravitational force when measuring the net force between two electrons. **P3.9B:** Provide examples that illustrate the importance of the electric force in everyday life.	
	Content Statement **P3.10 Electrical Induction** Charged objects can attract electrically neutral objects by induction. **Identifying and Using Performance expectations** **P3.10a:** Draw the redistribution of electric charges on a neutral object when a charged object is brought near. **P3.10b:** Identify examples of induced static charges. **P3.10c:** Explain why an attractive force results from bringing a charged object near a neutral object.
Inquiry, Reflecting, and Technology Performances	
Essential Inquiry and Technology **P3.R1** Design and critique methods to measure the net force resulting from two or more forces. **P3.R2** Compare your weight on Earth to your weight on	**Core Inquiry and Technology** **P3.r4** Validate that the electric force on an electron is much greater than the gravitational force on that electron using evidence from the Millikan Oil Drop experiment.

other planets using references. **P3.R3** Design and perform an investigation to determine the frictional forces between various surfaces and lubricants.	**P3.r5** Identify everyday situations where excess static charge may create a problem, and suggest solutions to the problems.
Boundaries	
Essential examples or observations vehicles in motion, satellites, lightning, clothes from dryer, plastic food wrap **Essential instruments and units of measure:** Quantitative measures of linear dimensions, mass, force, time Instruments: scales, accelerometers, electroscope, timers. **Essential representations** Graphs, data tables, force diagrams **Foundational knowledge** Magnetic forces of attraction and repulsion, friction	**Core examples or observations** electric motors, generators, projectile motion with horizontal initial velocity **Core instruments and units of measure** Computer probes, gates **Core representations** Strobe pictures, computer simulations

Michigan High School Science

CHEMISTRY

Prerequisite, Essential, and Core Content Statements and Expectations

CE • **RIGOR** • RELEVANCE • RELATIONSHIPS • RIGOR • RE
IPS • RELATIONSHIPS • RIGOR • **RELEVANCE** • RELAT
CE • RIGOR • RELEVANCE • RELATIONSHIPS • RIGOR • RE
IPS • **RELATIONSHIPS** • RIGOR • RELEVANCE • RELAT

MICHIGAN Department of Education

CHEMISTRY (C)

Properties of matter

All objects and substances in the natural world are composed of matter. All matter has two fundamental properties: matter takes up space, and matter has intertia – it changes motion only when under the influence of a non-zero net force. Matter can be characterized in terms of its physical and chemical properties. These properties can be explained through the particulate model of matter, which describes the particles as atoms or molecules that are continuously in motion. The extent of the motion can be used to explain the physical properties associated with the common states of matter, solid, liquid and gas, as well as the changes of state. Whether or not a particular substance will exist as a solid, liquid or a gas will depend on the force due to particle motion in comparison to the force of attraction between particles. The attractive forces between particles are explained by the detailed structure of molecules and the atoms that compose them.

The structure of an atom in terms of its component protons, neutrons and electrons provides the basis for a systematic description of the building blocks of matter and their organization in the Periodic Table of the Elements. The Periodic Table demonstrates the relationship between the number of protons in an element, which is the defining characteristic of each element, and the chemical and physical properties of the elements. The Periodic Table also provides a structure for inquiry into the characteristics of the elements, since the electronic structure of atoms is reflected in the arrangement of elements in the Periodic Table. It is the electronic structure of atoms, especially the outermost electrons, that explains the chemical properties of elements and the breaking and making of bonds between atoms in a chemical reaction. An understanding of the bonding between elements leads to the concept of molecules as particles with specific combinations of atoms. When a substance consists of only one type of molecule it is referred to as a compound, with each compound having unique chemical and physical pr operties due to the detailed structure of its component molecules.

Changes in matter

As a general principle, a great deal of understanding chemistry is in differentiating what Nobelist Roald Hoffmann deftly labeled as "the same and not the same." Chemistry is filled with comparisons that fall under this rubric. Isomerism, for instance, is built on this idea. Molecules have the same molecular formula, but have completely different properties (ethyl acetate and butyric acid). In photo- or thermal isomerization reactions, what constitutes the starting material and the product different on the basis of some observable property because here, too, the molecular formulas are the same. We create false dichotomies for the convenience of categorization (physical properties versus chemical properties, ionic versus covalent bonding), yet when you dissolve blue cobalt chloride in water, and the solution turns pick, it is hard to argue "dissolving is a simple act of physical change."

Are polymorphous crystalline forms that different? There are real property differences that we would traditionally include as "chemical" changes (spectroscopic differences, for instance). Is dissolving sodium chloride in water and then evaporating the water to get it back that different? Not really. Ionic networks or lattices are complex structures with billions and billions of degenerate isomeric forms. Add a sample of radio-labeled sodium chloride to a differently-labeled sample; crystallization accomplishes a cross-over experiment no matter how you look at it.

Changes in matter then, are not simple binary classifications, but derived from defining what is changing and the criteria by which those changes are judged, particularly those properties that are used to make the decision about what sort of change has taken place. A useful concept that helps sort through these relationships is "material kind," a term that us used when a substance is made up of a homogenous aggregate of atomic or molecular species (macroscopic "liquid water" is a "material kind," and differentiates it from the matter – molecular water: "HOH" – that comprises it). Solid water and liquid water are different material kinds, while the matter that makes them up is the same.

Forms of energy

From the chemical perspective it is critical that the student understand the role of energy in the breaking and formation of chemical bonds, since bond breaking/making is the fundamental process in a chemical reaction. Potential energy is stored energy resulting from the attraction between two objects. Students commonly only understand gravitational potential energy. Just as the force of gravity results in potential energy changes as objects are moved relative to the earth, there are changes in potential energy when any particles held by a force (gravitational, electrical, magnetic, strong) are moved relative to each other. Chemical bonds are the result of a decrease in potential energy from the increased electrostatic attractions between atoms. Chemical bonds will not form unless there is a decrease in potential energy compared to the unbonded state. The strength of a chemical bond is directly proportional to the energy released when the bond forms from the separated gaseous atoms (ions). Breaking a chemical bond always requires energy to overcome the attractive forces holding the particle (ions, atoms, molecules) together. At grade 8 the student should be able to describe physical changes (changes of state, dissolving) in terms of rearranging the atoms, molecules or ions). At grade 12 the student should be able to describe chemical changes in terms of bond making and bond breaking to demonstrate a deeper understanding of the term "chemical potential energy".

Energy transformations

The transfer of energy and the conservation of energy are of great explanatory and predictive value. Left on their own all systems will naturally move to a state of minimum energy and maximum randomness. Application of these two driving forces coupled with the conservation of matter and energy will allow students to explain and predict most chemical phenomena. Students will understand the tremendous energy released in nuclear reactions is a result of small amounts of matter being converted to energy.

Outline of Chemistry Expectations

Standard C1: Forms of Energy

C1.1x Chemical Potential Energy
C1.2 Molecules in Motion
C1.2x Molecular Entropy
C1.3x Breaking Chemical Bonds
C1.4x Electron Movement
C1.5x Nuclear Stability

Standard C2: Energy Transfer and Conservation

C2.1x Hess's Law
C2.2x Enthalpy
C2.3 Heating Impacts
C2.3x Bond Energy
C2.4 Endothermic and Exothermic Reactions
C2.4x Enthalpy and Entropy
C2.5 Nuclear Reactions
C2.5x Mass Defect

Standard C3: Properties of Matter

C3.1x Molecular and Empirical Formulae
C3.2x Nomenclature
C3.3 Describing Properties of Substances
C3.3x Solids
C3.4x Molecular Polarity
C3.5x Ideal Gas Law
C3.6x Moles
C3.7x Physical Properties of solutions
C3.8 Atomic Structure
C3.8x Electron Configuration
C3.9 Periodic Table
C3.9x Electron Energy Levels
C3.10 Neutral Atoms, Ions, and Isotopes
C3.10x Average Atomic Mass

Standard C4: Changes in Matter

C4.1x Rates of Reactions
C4.2 Chemical Changes
C4.2x Balancing Equations
C4.3x Equilibrium Constant
C4.4 Phase Change/ Diagrams
C4.4x Changes of State
C4.5 Chemical Bonds
C4.5x Classifying Chemical Bonds
C4.6x Reduction/Oxidation Reactions
C4.7 Acids and Bases
C4.7x Brónsted-Lowry
C4.8 Carbon Chemistry

Standard C1: Forms of Energy

Standard Statement

Students will recognize the many forms of energy and understand that energy is central to the predicting and explaining how and why chemical reactions occur. The chemical topics of bonding, gas behavior, kinetics, enthalpy, entropy, free energy, and nuclear stability will be addressed in this strand.

Chemistry students will need to relate temperature to the average kinetic energy of the molecules and to be able to use the kinetic molecular theory to describe and explain the behavior of gases and the rates of chemical reactions.

At the end of a full year of chemistry the student should understand nuclear stability in terms of reaching a state of minimum potential energy.

Content Statements, Performances, and Boundaries

Content Statements, Identifying and Using Performances, and Boundaries	
Essential	**Core**
Content statement **P1.p1** Three forms of potential energy are gravitational, elastic, and chemical. …. Objects can have elastic potential energy due to their compression, or chemical potential energy due to the arrangement of the atoms. *(Prerequisite)*	**Content Statement** **C1.1x Chemical Potential Energy** Potential energy is stored whenever work must be done to change the distance between two objects. The attraction between the two objects may be gravitational, electrostatic, magnetic, or strong force. Chemical potential energy is the result electrostatic attractions between atoms.
Identifying and Using Performance Expectations: Describe energy changes associated with changes of state in terms of the arrangement and order of the atoms (molecules) in each state. Use the positions and arrangements of atoms and molecules in solid, liquid and gas state to explain the need for an input of energy for melting and boiling and a release of energy in condensation and freezing. **Boundaries and Clarification:** Discussion limited to attractions between the atoms and molecules not to actual chemical bonds or intermolecular forces Emphasis on physical changes rather than chemical changes	**Identifying and Using Performance Expectations:** **C1.1a** Explain the changes in potential energy (due to electrostatic interactions) as a chemical bond forms and use this to explain why bond breaking always requires energy. **C1.1b** Describe energy changes associated with chemical reactions in terms of bonds broken and formed (including intermolecular forces). **C1.1c** Compare qualitatively the energy changes associated with melting various types of solids in terms of the types of forces between the particles in the solid. **Boundaries and Clarification:** Students should be able to compare the amount of energy in the reactants and products using qualitative diagrams showing energy as a function of reaction progress. Students should be able to make distinctions between types of chemical bonds (covalent, ionic, metallic) and intermolecular forces (dispersion, dipole-dipole, hydrogen bonding) in metallic, ionic, molecular, and covalent network solids when comparing bond energies.
Content Statement	**Content Statement**

C1.2 Molecules in Motion

Molecules that compose matter are in constant motion. Energy may be transferred from one object to another during collisions between molecules.

Identifying and Using Performance Expectations:

- **C1.2A** Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.
- **C1.2B** Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

Technical Vocabulary:

Activation energy

Boundaries and Clarification:

Limit to qualitative descriptions of "billiard ball" models of moving collections of particles.

C1.2x Molecular Entropy

As temperature increases the average kinetic energy and the entropy of the molecules in a sample increases.

Identifying and Using Performance Expectations:

- **C1.2c** Explain changes in pressure, volume and temperature for gases using kinetic molecular model.
- **C1.2d** Explain convection, and the difference in transfer of thermal energy for solids and liquids and gases using evidence that molecules are in constant motion.
- **C1.2e** Compare the entropy of solids, liquids, and gases.
- **C1.2f** Compare the average kinetic energy of the molecules in a metal object and a wood object at room temperature.

Boundaries and Clarification:

Students need to understand that the major difference between the solid and liquid state is the degree of order in the arrangement of atoms/molecules and not the distance between particles. They also need to define temperature in terms of the average kinetic energy of the particles.

$\frac{PV}{T} = \frac{P'V'}{T}$ use of Combined Gas Law required

Examination of balanced equations to predict changes in entropy based on states and numbers of gas molecules required.

While the term entropy means far more than "randomness" at this level the student will not be expected to understand entropy beyond comparing the changes in numbers of particles in a sample and their states as a result of a chemical reaction or phase change.

Content Statement:

1.3x Breaking Chemical Bonds

In order for molecules to react they must collide with enough energy (activation energy) to break old chemical bonds before their atoms can be rearranged to form new substances.

Identifying and Using Performance Expectations:

- **C1.3a** Explain how the rate of a given chemical reaction is dependent on the temperature and the activation energy.
- **C1.3b** Draw and analyze a diagram to show the activation energy for an exothermic reaction that is very slow at room temperature.

Boundaries and Clarification:

Limited to qualitative impact of temperature on rate.

Rate laws are not included

Content Statement

	C1.4x Electron Movement For each element the arrangement of electrons surrounding the nucleus is unique. These electrons are found in different energy levels and can only move from a lower energy level (closer to nucleus) to a higher energy level (further from nucleus) by absorbing energy in discrete packets. The energy content of the packets is directly proportional to the frequency of the radiation. These electron transitions will produce unique absorption spectra for each element. When the electron returns from an excited (high energy state) to a lower energy state energy is emitted in only certain wavelengths of light, producing an emission spectra. **Identifying and Using Performance Expectations:** **C1.4a** Describe energy changes in flame tests of common elements in terms of the (characteristic) electron transitions. **C1.4b** Contrast the mechanism of energy changes and the appearance of absorption and emission spectra. **C1.4c** Explain why an atom can absorb only certain wavelengths of light. **C1.4d** Compare various wavelengths of light (visible and nonvisible) in terms of frequency and relative energy. **Technical Vocabulary:** Electromagnetic spectrum, photon, wavelength, frequency and wave speed. **Boundaries and Clarification:** Student should relate color, wavelength and frequency for visible light. Students should compare relative energy of radiowaves, microwaves, infrared, ultraviolet, x-rays, and gamma rays. Student should be able to use Bohr model diagrams of main energy level transitions for absorption and emission spectra . Qualitative use of photoelectric effect required.
	Content Statement **C1.5x Nuclear Stability** Nuclear stability is related to decrease in potential energy when the nucleus forms from protons and neutrons. If the neutron/proton ratio is unstable the element will undergo radioactive decay. The rate of decay is characteristic of each isotope and the time for half the parent nuclei to decay is called the half-life. Comparison of the parent/daughter nuclei can be used to determine the age of a sample. Heavier elements are formed from the fusion of lighter elements in the stars.

	Identifying and Using Performance Expectations: **C1.5a** Illustrate how elements can change in nuclear reactions using balanced equations. **C1.5b** Describe the potential energy changes as two protons approach each other. **C1.5c** Describe how and where all the elements on earth were formed. **C1.5d** Determine the age of materials using the ratio of stable and unstable isotopes of a particular type. **Boundaries and Clarification:** First order rate equations for decay are not required. Essential technical vocabulary: Strong force, nuclear binding energy, half-life, mass defect, stable Vs unstable isotopes, carbon dating, parent isotopes, daughter isotopes
Inquiry, Reflecting, and Technology Performances	
C1.R1 Account for condensation of water vapor that appears on a cold surface in a humid environment. **C1.R2** When a few drops of food coloring is carefully added to water at three different temperatures (15^0C, 25^0C, 35^0C), it spreads out in the water to a significantly different degree depending on the temperature. What is the relationship between the extent of spread and temperature, and provide annotated drawings that explain what is happening at the molecular level.	**C1.r3** Develop an analogy for chemical energy stored in bonds (using) distance and attraction. **C1.r4** Determine absolute zero from extrapolation of temperature vs. pressure measurements and explain your reasoning. **C1.r5** Discuss the significance of the Kelvin temperature scale and why Kelvin temperatures must be used in all gas law problems. **C1.R6** Estimate average bond length by interpreting a graph of the distance between atoms Vs energy. **C1.r7** Explain why hydrogen is found in a plasma state in the sun but as a diatomic gas on earth. **C1.r8** Discuss limitations to the use of carbon-14 dating for artifacts. **C1.r10** Discuss the risks associated with coal powered power plants vs. nuclear fission power plants. **C1.r11** Design an experiment to compare the activation energy for different chemical reactions.

Standard C2: Energy Transfer and Conservation

Standard Statement

Students will apply the First and Second Laws of Thermodynamics to explain and predict most chemical phenomena.

Chemistry students will use the term enthalpy to describe the transfer of energy between reactants and products in simple calorimetry experiments performed in class and will recognize Hess's Law as an application of the conservation of energy.

Students will understand the tremendous energy released in nuclear reactions is a result of small amounts of matter being converted to energy.

Content Statements, Performances, and Boundaries

Content Statements, Identifying and Using Performances, and Boundaries	
Essential	**Core**
Content statement **P2.p1** When energy is transferred from one system to another, the quantity of energy before transfer equals the quantity of energy after transfer.*(Prerequisite)* **Identifying and Using Performance expectations:** Explain why the amount of energy required to melt (evaporate) substance is released when substance freezes (condenses). Calculate heat transfer from the initial and final temperature of a measured mass of water. **Technical Vocabulary:** Specific heat **Boundaries and clarification:** Calculations and measurements for simple calorimetry experiments required. **Essential equation:** $Q=mc\Delta t$	**Content statement** **C2.1x Hess's Law** For chemical reactions where the state and amounts of reactants and products are known, the amount of energy transferred will be the same regardless of the chemical pathway. This relationship is called Hess's law. **Identifying and Using Performance expectations:** **C2.1a** Calculate the Δ H for a given reaction using Hess's Law. **C2.1b** Draw enthalpy diagrams for exothermic and endothermic reactions. **C2.1c** Calculate the Δ H for a chemical reaction using simple coffee cup calorimetry. **C2.1d** Calculate the amount of heat produced for a given mass of reactant from a balanced chemical equation. **Boundaries and clarification:** Hess's Law problems will be limited to adding no more than 3 equations. Mole concept required for calculations
Content statement **P2.p2** Nuclear reactions take place in the sun. In plants, light from the sun is transferred to oxygen and carbon compounds, which, in combination, have chemical potential energy (photosynthesis)*(Prerequisite)* **Identifying and Using Performance expectations:** Trace (or diagram) energy transfers involving various types of energy including nuclear, chemical, electrical, sound, and light. **Boundaries and clarification:**	**Content statement** **C2.2x Enthalpy** Chemical reactions involve breaking bonds in reactants (endothermic) and forming new bonds in the products (exothermic). The enthalpy change for a chemical reaction will depend on the relative strengths of the bonds in the reactants and products. **Identifying and Using Performance expectations:** **C2.2a** Describe the energy changes in photosynthesis and in the combustion of sugar in terms of bond breaking and bond making. **C2.2b** Describe the relative strength of single, double, and triple covalent bonds between nitrogen atoms. **Essential vocabulary:** Exothermic, endothermic, Enthalpy **Boundaries and clarification:** Use of bond energies to calculate ΔH only required when structures of reactants and products are given.
Content statement **C2.3 Heating Impacts** Heating increases the translational, rotational, and vibrational energy of the atoms composing elements and the molecules or ions composing compounds. As the translational energy of the atoms, molecules, or ions increases, the temperature of the matter increases.	**Content statement** **C2.3x Bond Energy** Chemical bonds possess vibrational and rotational energy. The bond can be modeled as an oscillating spring.

Heating a sample of a crystalline solid increases the vibrational energy of the atoms, molecules, or ions. When the vibrational energy becomes great enough, the crystalline structure breaks down and the solid melts. **Identifying and Using Performance expectations:** **C2.3A** Describe how heat is conducted in a solid. **C2.3B** Describe melting on a molecular level. **Boundaries and clarification:**	**Identifying and Using Performance expectations:** **C2.3c** Explain why chemical bonds do not have a fixed length. **C2.3d** Explain why it is necessary for a molecule to absorb energy in order to break a chemical bond. **Boundaries and clarification:** IR spectrophotometry not included
Content statement **C2.4 Endothermic and Exothermic** Chemical interactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic). **Identifying and Using Performance expectations:** **C2.4A** Use the terms endothermic and exothermic correctly to describe chemical reactions in the laboratory. **C2.4B** Explain why chemical reactions will either release or absorb energy. **Boundaries and clarification:** Term enthalpy not required	**Content Statement** **C2.4x Enthalpy and Entropy** All chemical reactions involve rearrangement of the atoms. In an exothermic reaction the products have less energy than the reactants. There are two natural driving forces (1) toward minimum energy (enthalpy) (2) toward maximum disorder (entropy). **Identifying and Using Performance Expectations:** **C2.4c** Write chemical equations including the heat term as a part of equation or using ΔH notation. **C2.4d** Draw enthalpy diagrams for reactants and products in endothermic and exothermic reactions. **C2.4e** Predict if a chemical reaction is spontaneous given the enthalpy (ΔH) and entropy (ΔS) changes for the reaction. **C2.4f** Explain why some endothermic reactions are spontaneous at room temperature. **C2.4g** Explain why gases are less soluble in warm water than cold water. **Boundaries and Clarification:** Extended technical vocabulary: enthalpy, entropy, Gibb's Free Energy, $\Delta G= \Delta H - T\Delta S$ Calculations of ΔH^0 from H_f^0 and ΔS from S^0 are not required.
Content statement **C2.5 Nuclear Reactions** Nuclear reactions, fission and fusion, convert matter into appreciable amounts of energy. **Identifying and Using Performance expectations:** **C2.5A** Compare qualitatively the relative energy of physical, chemical and nuclear changes. **Boundaries and clarification:** Actual calculations of mass defect are not required nor is the calculation of $E=mc^2$	**Content statement** **C2.5x Mass Defect** Nuclear reactions involve energy changes many times the magnitude of chemical changes. In chemical reactions matter is conserved but in nuclear reactions a small loss in mass (mass defect) will account for the tremendous release of energy. The energy released in nuclear reactions can be calculated from the mass defect using $E=mc^2$ **Identifying and Using Performance expectations:** **C2.5b** Explain why matter is not conserved in nuclear reactions. **Boundaries and clarification:**

	Actual calculations of mass defect are not required nor is the calculation of $E=mc^2$
Inquiry, Reflecting, and Technology Performances	
C2.R1 Design an experiment to determine the specific heat of a metal sample. **C2.R2** Explain why a piece of metal will feel cooler than a piece of wood both at room temperature? **C2.R3** Evaluate the use of nuclear energy vs. coal power plants. **C2.R4** Discuss how the destruction of forests might exacerbate the greenhouse effect. **C2.R5** Discuss two advantages of using nuclear fusion vs. nuclear fission for power.	**C2.r6** Interpret a phase diagram for heating a substance in terms of changes in kinetic and potential energy. **C2.r7** Design an experiment to verify Hess's law using a simple calorimeter to determine the Δ H for an individual reactions. **C2.r8** Explain why the heating ice results in a decrease in volume. **C2.r9** Explain why many explosives contain nitrogen. **C2.r10** Forming nitrogen compounds for plant fertilizer from N_2 is very difficult. **C2.r12** Explain why Hess's Law is really another way to state that energy is never created or destroyed.

Standard C3: Properties of Matter

Standard Statement

Compounds, elements and mixtures are categories used to organize matter and the students should be familiar with organizing materials into these categories based on their chemical and physical behavior. Students will need to understand the structure of the atom to make predictions about the physical and chemical properties of various elements and the types of compounds those elements will form. An understanding of the organization the Periodic Table in terms of the outer electron configuration is one of the most important tools for the chemist and student to use in prediction and explanation of the structure and behavior of atoms.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances, and Boundaries	
P3.p1 Properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion. *(Prerequisite; See KMT under energy transfer.)* **Identifying and Using Performance Expectations** For a substance that can exist in all three phases, describe the relative motion of the particles in each of the phases. For a substance that can exist in all three phases, make a drawing that shows the arrangement and relative spacing of the particles in each of the phases. For a simple compound, present a drawing that shows the number of particles in the system does not change as a result of a phase change. **Boundaries and Clarification:** Do not include compounds that decompose on heating.	
P3.p2 Elements are a class of substances composed of a single	**C3.1x Molecular and Empirical Formulae**

kind of atom. Compounds are composed of two or more different elements chemically combined. Mixtures are composed of two or more different elements and or compounds physically combined. Each element and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample. *(Prerequisite)* **Identifying and Using Performance Expectations** Distinguish between an element, compound or mixture based on drawings or formulas. Identify a pure substance (element or compound) based on unique chemical and physical properties. Separate mixtures based on the differences in physical properties of the individual components Recognize that the properties of a compound differ from those of its individual elements **Boundaries and Clarification:** Limit the mixture to three substances.	Compounds have a fixed percent elemental composition. Empirical formula for a compound can be calculated from the percent composition or the mass of each element. To determine the molecular formula from the empirical formula, the molar mass of the substance must also be known. **Identifying and Using Performance Expectations** **C3.1a** Calculate the percent by weight of each element in a compound based on the compound formula. **C3.1b** Calculate the empirical formula of a compound based on the percent by weight of each element in the compound. **C3.1c** Use the empirical formula and molecular weight of a compound to determine the molecular formula. **Boundaries and Clarification**: Empirical formula calculations limited to no more than 3 elements. Combustion analysis for determining empirical formulas is not included.
	C3.2x Nomenclature All compounds have unique names that are determined systematically. **Identifying and Using Performance Expectations** **C3.2a** Given the formula, name simple binary compounds. **C3.2b** Given the name, write the formulas of simple binary compounds. **C3.2c** Given the formula for a simple hydrocarbon draw and name the isomers. **Technical Vocabulary:** Metals, non metals, metalloids, ionic compounds, covalent compounds. **Boundaries and Clarification:** Naming binary ionic compounds using the IUPAC conventions, no traditional names. Include common polyatomic ions (CO_3^{-2}, SO_4^{-2}, NO_3^{-1}, PO_4^{-3}, NH_4^{+1}) Binary acids and the acids of the polyatomic ions Binary molecular compounds, such as CO2, CO, SO2 Organic names limited to 10 carbon or less hydrocarbons
C.3.3 Describing Properties of Substances Differences in the physical and chemical properties of	**C3.3x Solids** Solids can be classified as metallic, ionic, covalent,

substances are explained by the ways in which the atoms, ions, or molecules of the substances are arranged and the strength of the forces of attraction between the atoms, ions, or molecules. **Identifying and Using Performance Expectation:** **C3.3A** Recognize that substances that are solid at room temperature have stronger attractive forces than liquids at room temperature, which have stronger attractive forces than gases at room temperature. **C3.3B** Compare the relative strengths of forces between molecules based on the MP and BP of the substances. **C3.3C** Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases. **C3.3D** Compare the strength of the forces of attraction between the molecules of the two elements knowing that Chlorine is a gas at room temperature and iodine is a solid. **Boundaries and Clarification**:	network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid. **Identifying and Using Performance Expectation:** **C3.3e**, Predict whether the forces of attraction in a solid are primarily metallic, covalent, network covalent, or ionic based upon the elements' location on the periodic table. **C3.3f** Identify the elements necessary for hydrogen bonding (N, O, F) **C3.3g** Given the structural formula of a compound, indicate all the intermolecular forces present (dispersion, dipolar, hydrogen bonding). **C3.3h** Explain properties of various solids such as malleability, conductivity and melting point in terms of the solid's structure and bonding? **C3.3i** Explain by NaF has a melting point of 995^0C while water has a melting point of 0^0C. **Boundaries and Clarification:** Limit to common binary salts and covalent compounds, network covalent limited to diamonds, silicates, metals limited to elements (not alloys).
	C3.4x Molecular Polarity The forces between molecules depend on the net polarity of the molecule as determined by shape of the molecule and the polarity of the bonds. **Identifying and Using Performance Expectation:** **C3.4a** Explain why at room temperature different compounds can exist in different phases. **C3.4b** Identify if a molecule is polar or nonpolar given a structural formula for the compound. **Boundaries and Clarification:** Structural formulas will be provided showing shapes of molecules.
	C3.5x Ideal Gas Law The forces in gases are explained by the ideal gas law. (See Energy unit for KMT and related) **Identifying and Using Performance Expectation:** **C3.5a** Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume relationship in gases. **C3.5b** Provide macroscopic examples, atomic and molecular explanations, and mathematical

	representations (graphs and equations) for the pressure-temperature relationship in gases. **C3.5c** Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the temperature-volume relationship in gases. **Boundaries and Clarification:** Limit to explicit binary (PV, PT, VT) relationships.
	C3.6x Moles The mole is the standard unit for counting atomic and molecular particles in terms of common mass units. **Identifying and Using Performance Expectation: :** **C3.6a** Calculate the number of moles of any compound or element given the mass of the substance. **C3.6b** Calculate the number of particles of any compound or element, given the mass of the substance. **Boundaries and Clarification:**
	C3.7x Physical Properties of Solutions The physical properties of a solution are determined by the concentration of solute. **Identifying and Using Performance Expectation:** **C3.7a** Investigate the difference in the boiling point or freezing point of pure water and a salt solution **C3.7b** Compare the density of pure water to that of a sugar solution. **Technical Vocabulary:** Molarity, solute, solvent, solution, saturation, supersaturation. **Boundaries and Clarification:**
C3.8 Atomic Structure Electrons, protons, and neutrons are parts of the atom and have measurable properties including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons. **Identifying and Using Performance Expectation:**	**C3.8x Electron Configuration** Electrons are arranged in main energy levels with sub-levels that specify particular shapes and geometry. Orbitals represent a region of space in where an electron may be found with a high level of probability. Each defined orbital can hold two electrons, each with a specific spin orientation. The specific assignment of an electron to an orbital is determined by a set of 4 quantum numbers. Each element, and therefore each position in the periodic table, is defined by a unique set of quantum numbers. **Identifying and Using Performance Expectation:** **C3.8e** Write the complete electron configuration of

C3.8A Identify the location, relative mass and charge for electrons, protons and neutrons.

C3.8B Describe the atom as mostly empty space with an extremely small, dense nucleus consisting of the protons and neutrons and an electron cloud surrounding the nucleus.

C3.8C Recognize that protons repel each other and that there needs to be a strong force present to keep the nucleus intact.

C3.8D Give the number of electrons and protons present if the fluoride ion has a -1 charge.

Boundaries and Clarification:

Do not include sub-nuclear particles such as quarks in the discussion.

Electron configuration, quantum numbers not part of this discussion. See extension for electronic configuration.

Identify in a series of atoms and ions the ones that have the same electron configuration.

There are three isotopes for hydrogen, explain that these are all hydrogen, yet different in mass.

elements in the first four rows of the periodic table.

C3.8f Write kernel structures for main group elements.

C3.8g Predict oxidation states and bonding capacity for main group elements using their electron structure.

C3.8h Describe the shape and orientation of s and p orbitals.

C3.8i Describe the fact that the electron location cannot be exactly determined at any given time.

Boundaries and Clarification:

Complete electron configuration limited to the first four periods.

Kernel structures for main group elements.

Assignment of quantum numbers not required.

C3.9 Periodic Table

In the Periodic Table, elements are arranged in order of increasing number of protons (called the atomic number). Vertical groups in the periodic table (families) have similar physical and chemical properties due to the same outer electron structures.

Identifying and Using Performance Expectation:

C3.9A Identify elements with similar chemical and physical properties using the periodic table.

Boundaries and Clarification:

Limit to main group families

C3.9x Electron Energy Levels

The rows in the periodic table represent the main electron energy levels of the atom. Within each main energy level are sublevels that represent an orbital shape and orientation.

Identifying and Using Performance Expectation:

C3.9b Write electron configurations for the first four rows using the periodic table.

C3.9c Identify metals, non-metals and metalloids using the periodic table.

C3.9d Predict general trends in atomic radius and first ionization energy of the elements using the periodic table.

Boundaries and Clarification:

C3.10 Neutral Atoms, Ions, and Isotopes

A neutral atom of any element will contain the same number of protons and electrons. Ions are charged particles with an unequal number of protons and electrons. Isotopes are atoms of the same element with different numbers of neutrons and essentially the same chemical and physical properties.

Identifying and Using Performance Expectation:

C3.10A List the number of protons, neutrons and electrons for any given ion or isotope.

C3.10B Recognize that an element always contains the same number of protons.

C3.10x Average Atomic Mass

The atomic mass listed on the periodic table is an average mass for all the different isotopes that exist, taking into account the percent and mass of each different isotope.

Identifying and Using Performance Expectation:

C3.10c Calculate the average atomic mass of an element given the percent abundance and mass of the individual isotopes.

C3.10d Predict which isotope will have the greatest abundance given the possible isotopes for an element, along with the average atomic mass in the periodic table.

Boundaries and Clarification:	**C3.10e** Write the symbol for an isotope, $_{Z}^{A}X$, where Z is the atomic number, A is the mass number and X is the symbol for the element **Boundaries and Clarification:** Limit the calculations to elements with no more than three isotopes. Limit to H, C, Cl,
Inquiry, Reflecting, and Technology Performances	
C3.R1 Describe a method of separating a mixture **C3.R2** Determine whether a substance is an element, compound, or a mixture **C3.R3** Explain why isotopes of an element should have the same physical and chemical properties and why this is important. **C3.R4** Explain why ions have different chemical properties than their neutral atoms and why this is important. **C3.R5** Discuss the historical development of the periodic table	**C3.r6** Design an activity that will allow you to identify the type of solid based on simple laboratory tests such as melting point, conductivity, solubility. **C3.r7** Predict the number of atoms in a sample with the exact atomic mass listed in the periodic table. **C3.r8** Develop your own analogy for describing the location of the electron. **C3.r9** Discuss the importance of the periodic law and the reason why Mendeleev is given credit for the periodic table.

Standard C4: Changes in Matter

Standard Statement

Students should be able to analyze a chemical change phenomenon from the point of view of what is the same and what is not the same.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances, and Boundaries	
P4.p1 Changes of state are explained by a model of matter composed of tiny particles that are in motion. When substances undergo changes of state, neither atoms nor molecules themselves are changed in structure. Mass is conserved when substances undergo changes of state.*(Prerequisite)* **Identifying and Using Performance Expectation:** Draw a picture of the particles of a element or compound as a solid, liquid and gas. **Boundaries and Clarification:**	**Content Statement** **C4.1x Rates of Reactions** The rate of a chemical reaction will depend upon (1) concentration of reacting species (2) temperature of reaction (3) pressure if reactants are gases (4) nature of the reactants. A model of matter composed of tiny particles that are in constant motion is used to explain rates of chemical reactions. **Identifying and Using Performance Expectation:** **C4.1a** Predict how the rate of a chemical reaction will be influenced by changes in concentration, temperature, pressure. **C4.1b** Explain how the rate of a reaction will

	depend of concentration, temperature, pressure, and nature of reactant. **Boundaries and Clarification:** Rate laws are not included
Content Statement: **C4.2 Chemical Changes** Chemical changes can occur when two substances, elements, or compounds interact and produce one or more different substances, whose physical and chemical properties are different from the interacting substances. When substances undergo chemical change, the number of atoms in the reactants is the same as the number of atoms in the products. Mass is conserved when substances undergo chemical change. The total mass of the interacting substances (reactants) is the same as the total mass of the substances produced (products). **Identifying and Using Performance Expectations** **C4.2A** Balance simple chemical equations applying the conservation of matter. **C4.2B** Distinguish between chemical and physical changes in terms of the properties of the reactants and products. **C4.2C** Draw pictures to distinguish the (relatonships between?)atoms in physical and chemical changes. **Boundaries and Clarification:** Limited to equations that can be balanced by "trial and error" method. Formula writing not required.	**Content Statement:** **C4.2x Balancing Equations** A balanced chemical equation will allow one to predict the amount of product formed. **Identifying and Using Performance Expectations** **C4.2d** Calculate the mass of a particular compound formed from the masses of starting materials. **C4.2e** Identify the limiting reagent when given masses (of) more than one reactant. **C4.2f** Predict volumes of product gases using initial volumes of gases at the same temperature and pressure. **C4.2g** Calculate the number of atoms present in a given mass of element. **Boundaries and Clarification**: . The mole concept is essential in chemical calculations Calculations to include: mass/mass, moles/mole, mass/volume, limiting reagent **Technical Vocabulary:** limiting reactant, excess reactant, Avagodro's #, % completetion, % error.
	Content statement: **C4.3x Equilibrium Constant** Most chemical reactions reach a state of dynamic equilibrium where the rate of the forward and reverse reaction are equal. The equilibrium constant represents the ratio of products to reactants at equilibrium. **Identifying and Using Performance expectations:** **C4.3a** Predict shifts in a chemical system caused by changing conditions using Le Chatelier's Principle. **C4.3b** Predict the extent reactants are converted to products using the value of the equilibrium constant.

	Boundaries and clarification: Calculations involving K are not required. **Technical Vocabulary:** Equilibrium, Le'Chatlier's Principle, molarity,
Content statement: **C4.4 Phase Change/Diagrams** Changes of state require a transfer of energy. Water has unusually high-energy changes associated with its changes of state. **Identifying and Using Performance Expectations** **C4.4A** Compare the energy required to raise the temperature of one gram of aluminum and 1 gram of water the same number of degrees? **C4.4B** Measure, plot and interprete the graph of the temperature versus time of an ice-water mixture, under slow heating, through melting and boiling. **C4.4C** Draw a series of representations, or create an animation, that illustrates the changes that take place in a group of 20 water molecules as a sample of ice is melted. **Boundaries and Clarification:** $Q=mc\Delta t$	**Content statement:** **C4.4x Changes of State** All changes of state require energy. Changes in state that require energy involve breaking forces holding the particles together. The amount of energy will depend on the type of forces. **Identifying and Using Performance Expectations** **C4.4d** Explain why both the melting point and boiling points for water are significantly higher than other small molecules of comparable mass (e.g., ammonia and methane). **C4.4e** Explain why freezing is an exothermic change of state. **C4.4f** Compare the melting point of covalent compounds based on the strength of IMF's (intermolecular forces) **Boundaries and Clarification:** Chemical bonds and intermolecular forces for melting metallic, ionic, molecular, and network covalent solids Hydrogen bonding, dispersion or London forces, dipole **Technical Vocabulary:** Heat of vaporization, heat of fusion, latent heat, evaporation, condensation, sublimation, melting and freezing
Content statement: **C4.5 Chemical Bonds** An atom's electron configuration, particularly of the outermost electrons, determines how the atom can interact with other atoms. The interactions between atoms that hold them together in molecules are called chemical bonds. **Identifying and Using Performance Expectations** **C4.5A** Predict if the bonding between two atoms of different elements will be primarily ionic or covalent. **C4.4B** Predict the formula for binary compounds of main group elements. **Boundaries and Clarification:**	**Content statement:** **C4.5x Classifying Chemical Bonds** Chemical bonds can be classified as ionic, covalent and metallic. The properties of a compound ~~will~~ depend on the types of bonds holding the atoms together. **Identifying and Using Performance Expectations** **C4.5c** Draw Lewis structures for simple compounds. **C4.5d** Compare the relative melting point, electrical and thermal conductivity, and hardness for ionic, metallic, and covalent compounds. **C4.5e** Relate the melting point, hardness, electrical and thermal conductivity, of a substance to its structure. **Boundaries and Clarification:**

Limited to common elements and to binary compounds.	Lewis structures for covalent compounds limited to 4 atoms. **Technical vocabulary:** Lewis structures, octet rule, polarity, bond geometry, bond angles and central atom.
	Content statement: **C4.6x Reduction/Oxidation Reactions** Chemical reactions are classified according to the fundamental molecular or sub-molecular changes that occur. Reactions that involve electron transfer are known as oxidation/reduction (or "redox"). **Identifying and Using Performance Expectations;** **C4.6a** Balance half-reactions and describe them as oxidations or reductions. **C4.6b** Predict single replacement reactions. **C4.6c** Explain oxidation occurring when two different metals are in contact. **C4.6d** Calculate the voltage for spontaneous redox reactions from the Standard Reduction potentials. **C4.6e** Identify the reactions occurring at the anode and cathode in an electrochemical cell. **Boundaries and Clarification:** Standard Reduction Potentials provided **Technical Vocabulary:** Half reactions, reducing agent, oxidizing agent, oxidation #, anode, cathode, voltage and galvanic cells.
Content statement: **C4.7 Acids and Bases** Acids and bases are important classes of chemicals that are recognized by easily observed properties in the laboratory. Acids and bases will neutralize each other. Acid formulas usually begin with hydrogen and base formulas are a metal with a hydroxide ion. As the pH decreases a solution becomes more acidic. A difference of one pH unit is a factor of 10 in hydrogen ion concentration. **Identifying and Using Performance Expectations** **C4.7A** Recognize formulas for common inorganic acids, carboxylic acids, and bases formed from families I and II. **C4.7B** Predict products of an acid-base neutralization. **C4.7C** Describe tests that can be used to distinguish an acid from a base. **C4.7D** Classify various solutions as acidic or basic, given their pH. **C4.7E** Explain why lakes with limestone or calcium	**Content statement:** **C4.7x Brǿnsted-Lowry** Chemical reactions are classified according to the fundamental molecular or sub-molecular changes that occur. Reactions that involve proton transfer are known as acid/base reactions. **Identifying and Using Performance Expectations:** **C4.7f** Write balanced chemical equations for reactions between acids and bases and perform calculations (what type of calculation?) with balanced equations. **C4.7g** Identify the Bronsted-Lowry conjugate acid-base pairs in an equation. **C4.7h** Calculate the pH from the hydronium ion or hydroxide ion concentration. **C4.7i** Explain why sulfur oxides and nitrogen

carbonate experience less adverse effects from acid rain than lakes with granite beds. **Boundaries and Clarification:** Arrhenius theory Calculation of pH not required.	oxides contribute to acid rain **Boundaries and Clarification:** Titration, Bronsted-Lowry theory Calculation of pH at 25^0C and limited to 1 x 10^{-x} when x is between 1 and 14. **Technical Vocabulary:** Acid anhydrides (C4.7i), hydromium ion, conjugates, logarithms.
Content statement: **C4.8 Carbon Chemistry** The chemistry of carbon is important. Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life. **Identifying and Using Performance Expectations** **C4.8A** Draw structural formulas for up to ten carbon chains of simple hydrocarbons. **C4.8B** Draw isomers for simple hydrocarbons. **C4.8C** Recognize (that) proteins, starches, and other large biological molecules are polymers. **Boundaries and Clarification:**	
Inquiry, Reflecting, and Technology Performances	
C4.R1 Suggest an appropriate antidote for spilling acid on one's skin.(and why you choose it) **C4.R2** Explain why carbon's structure allows it to be the basic building block of living things. **C4.R3** Comment on the significance of a drop from pH=5 to pH=3 in a lake. **C4.R4** Discuss why cities near large bodies of water experience less dramatic temperature changes than cities inland.	**C4.r5** Design an experiment to investigate the affect of concentration and temperature on the rate of a chemical reaction. **C4.r6** Design an experiment to determine the percent yield for a simple chemical reaction such as formation of NaCl from baking soda and acid. **C4.r7** Design an experiment to find the concentration of an unknown acid using a base of known concentration. **C4.r8** Suggest appropriate metal nails to use with aluminum siding. **C4.r9** Construct an electrochemical cell of maximum voltage. **C4.r10** Design a laboratory procedure for classifying various solids as metallic, ionic, covalent, or network covalent. **C4.r11** Use Le Chatelier's principle to suggest conditions that will maximize product yield.

Appendix A: Basic Knowledge and Skills

This section contains basic knowledge and skills that are necessary for successful performance in all disciplines, including the following:

Prerequisite Knowledge and Skills

Basic Science Knowledge

Scientific Method

Reading, Writing, Communication

Orientation Towards Learning

Basic Mathematics Conventions, Probability, Statistics, Measurement

MICHIGAN Department of Education
Office of School Improvement

Michigan Department of Education
Office of School Improvement
Dr. Yvonne Caamal Canul, Director
(517) 241-3147 www.michigan.gov/mde