Michigan High School Science

PHYSICS

Prerequisite, Essential, and Core Content Statements and Expectations

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Office of School Improvement

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:

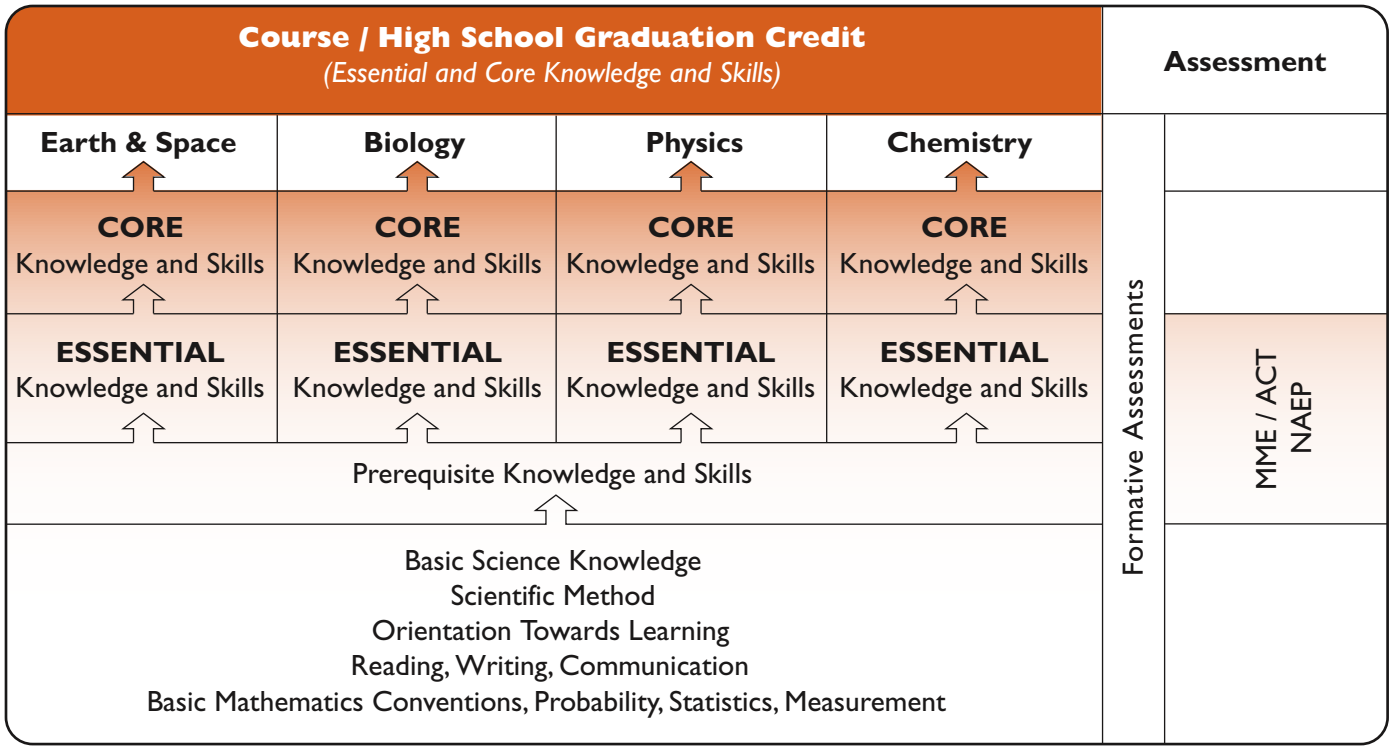
- **Prerequisite knowledge**
  Useful and connected knowledge that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed in the Essential category. Prerequisite content statements and expectations will be included in the 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.

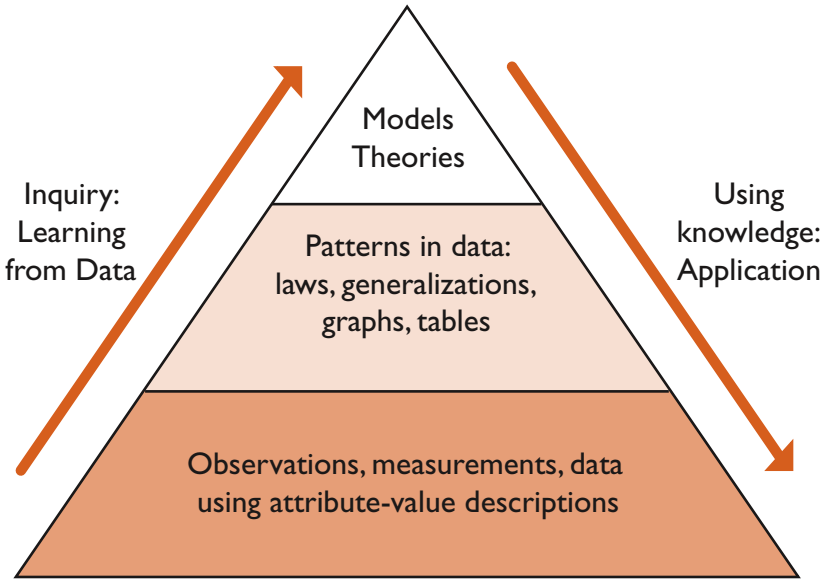


Figure 1: Knowledge and practices of model-based reasoning

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.

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 **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	**Core: Inquiry and Technology** **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, **Essential instruments and units of measure** Qualitative descriptions of physical properties: conductivity of heat and electricity, joules, degrees **Essential representations** Energy transfer diagrams, graphs and tables	**Core examples or observations** ski lifts, ripple tanks, fuses, circuit breakers, water heater, power plants, **Core instruments and units of measure** drawing compass, light sources (boxes), optical bench, lenses, mirrors, thermometers, calories**,** **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). .
	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

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Dr. Yvonne Caamal Canul, Director
(517) 241-3147 www.michigan.gov/mde