Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponential and logarithmic functions, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
• Use mathematical representations of phenomena to describe explanations.
• Create a computational model or simulation of a phenomenon, designed device, process, or system.

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.
• Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

Crosscutting Concepts

Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
• Systems can be designed to cause a desired effect.

Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.
• Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Energy and Matter
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
• Energy cannot be created or destroyed—only moves between one place and another, between objects and/or fields, or between systems.

Measurement Skills Hypothesis Skills Conclusion Skills Data Skills

- Students can differentiate between English System and Metric System units. Students know metric prefixes and the value associated with each.
  - Definition: A testable statement, that includes experimental variables about the natural world based on research, prior knowledge, and/or observations.
  - Definition: A statement of whether the hypothesis was or was not supported by the data. Should include the results of experiment, a comparison to the hypothesis, and calculation of % error.
- Students can accurately measure with a metric ruler, stop watch, beaker, thermometer, graduated cylinder, and triple beam balance.
  - Definition: Students are designing and executing experiments based on their hypothesis. Students are writing hypothesis in if…then…because format, all written by the student.
  - Use technology to create graphs.
- Students expected to measure with estimates made into an interval on the measurement tool. Students understand how much can be estimated.
  - Students are designing and executing experiments based on their hypothesis. Students are writing hypothesis in if…then…because format, all written by the student.
  - Use technology to create graphs.

Pacing Guides create a realistic time frame for instruction and assessment. They establish paced, student learning expectations and provide a starting point for the implementation of the Michigan State Standards.

The following tips may be helpful as you begin using the Pacing Guide:

- Introduce 9-week content skills according to the Pacing Guide.
- Once a skill is mastered, continue to practice it.
- Continue to reinforce skills and concepts throughout the year until mastery is achieved.
- Skills can be introduced earlier than listed, but no later, and can be assessed at any point after introduction.
- Compare your current pace to the Pacing Guide and adjust as needed.
- Become familiar with sequencing at previous and subsequent grade levels.
- The website, www.nextgenscience.org, can be used to find more information and to better understand Michigan State Standards.
- An electronic version of the Pacing Guides can be found on the Lansing School District homepage www.lansingschools.net under Quiklinks.
I CAN Statements

<table>
<thead>
<tr>
<th>Unit 1 Motion and Forces</th>
<th>Unit 2 Momentum and Impulse</th>
<th>Unit 3 Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ I CAN design, and conduct an investigation to determine the relationship between force, mass, and acceleration. ☐ I CAN use Newton’s Law of Gravitation to predict the changes in the gravitational force between two objects when the mass of the objects or distance between objects changes. ☐ I CAN support the claim that the total momentum in a system of objects is conserved when there is no net force on the system. ☐ I CAN design, evaluate, and modify a device that minimizes the force on an object during a collision (such as a container holding an egg that is dropped). ☐ I CAN design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. ☐ I CAN use the law of conservation of energy to calculate changes in energy of one component in a system when changes in the energy of the other components and the energy flows in the system are known. ☐ I CAN develop and use models to illustrate that energy cannot be created or destroyed, it only trasforms from one form to another.</td>
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Standard HS PS2.1

Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Clarification: Determine from acceleration-force data and acceleration-mass data that acceleration is directly proportional to force and inversely proportional to mass. Determine relative forces or masses of objects from a velocity-time graph. Data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Standard HS PS2.2

Use mathematical representations of Newton’s Law of Gravitation to describe and predict the gravitational and electrostatic forces between objects.

Clarification: Realize that the mathematical representation of a gravitational field is only predicts an attractive force because mass is always positive.

Standard HS PS2.3

Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Clarification: Explain in terms of force, time, impulse, and momentum, how and why things like air bags in vehicles and padding in football helmets reduce the force of impact in a collision. When developing the device to minimize forces in a collision, constraints such as cost, safety, reliability, and aesthetics as well as social, and environmental impacts should be taken into consideration.

Disciplinary Core Ideas

- Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- Newton’s second law accurately predicts changes in the motion of macroscopic objects.
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- Momentum is defined for a particular frame of reference: it is the mass times the velocity of the object.
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
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- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in one place moves across space.
- Additional...
Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.

• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design; decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

• Develop & use a model based on evidence to illustrate relationships between systems or between components of a system.

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

• Use mathematical representations of phenomena to describe explanations.

• Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Crosscutting Concepts

Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Cause and Effect
• Empirical evidence is required to differentiate between cause & correlation and make claims about specific causes & effects.

• Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

• Systems can be designed to cause a desired effect.

Stability and Change
• Systems can be designed for greater or lesser stability.

Measurement Skills

Hypothesis Skills

Conclusion Skills

Data Skills

• Students can differentiate between English System and Metric System units. Students know metric prefixes and the value associated with each.

• Students can accurately measure with a metric ruler, stop watch, beaker, thermometer, graduated cylinder, and triple beam balance.

• Students expected to measure with estimates between marked intervals on the measurement tool. Students understand how much can be estimated.

Definition: A testable statement, that includes experimental variables about the natural world based on research, prior knowledge, and/or observations.

• Students are designing and executing experiments based on their hypothesis. Students are writing hypothesis in if … then … because format, all written by the student.

• Students can label axes with variable and units.

• Students can determine function of the graph.

• Students can calculate slopes and y-intercepts.

• Students can read graphs with a double y-axis.

• Students can create line of best fit and determine function of the graph.

• Students can identify independent/dependent variable.

• Students can create scales for each axis.

• Students can label axis with variable and units.

Introduction to Your Science Pacing Guide

The Science Pacing Guide is based on the Next Generation Science Standards, and the I CAN statements are tailored to the needs of the students in the Lansing School District. For easy access to the actual state standards as well as supporting information and resources visit the official Next Generation Science Standards website at www.nextgenscience.org.

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Many thanks to…

the teachers and administrators who helped develop and revise the pacing guides.

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The Science Pacing Guide is

Physics • Second Quarter
<table>
<thead>
<tr>
<th><strong>Physics</strong></th>
<th><strong>Science</strong></th>
<th><strong>Second Quarter</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit 4 Waves</strong></td>
<td><strong>Unit 5 Electricity and Magnetism</strong></td>
<td><strong>I CAN Statements</strong></td>
</tr>
<tr>
<td>- I CAN use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</td>
<td>- I CAN use Coulomb’s law to describe and predict electrostatic forces between objects. PS2.4</td>
<td>- I CAN use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. PS2.5</td>
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<tr>
<td>- Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.</td>
<td>- Use mathematical representations of Coulomb’s Law to describe and predict electrostatic forces between objects. PS2.4</td>
<td>- I CAN plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.</td>
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<td>- Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</td>
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<td>- Clarification: Show that the product of the frequency and the wavelength of a particular type of wave in a given medium is a constant, the wave speed. When given two of the three variables in ( v = \lambda f ), solve for the third variable. Predict the relative change in wavelength of a wave when it moves from one medium to another and express the relative change in terms of cause (different media) and effect (different wavelengths, but same frequency).</td>
<td>- Clarification: Emphasis is on both quantitative and conceptual descriptions of Coulomb’s law. Realize that it predicts both attractive and repulsive forces because electric charge can be positive and negative. Predict changes in the electrical force between two charged objects when the quantity of charge or distance between changes (e.g., if distance doubles, force will be 1/4 of what it was originally). Students should describe how some devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Examples of devices that use wave behavior to transmit information/energy include solar cells, medical imaging, and communications technology (e.g., fiber optics). One device should depend on the photoelectric effect. Students should evaluate questions about the advantages of using a digital transmission and storage of information.</td>
<td>- Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. Clarification: Understand conceptually (no formulas needed) the factors that affect the strength of an electromagnet and the amount of current resulting from electromagnetic induction.</td>
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<td>- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.</td>
<td>- Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.</td>
<td>- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents can produce magnetic fields; electric charges or changing magnetic fields cause electric fields. “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.</td>
</tr>
<tr>
<td>- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.</td>
<td>- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining features of electromagnetic radiation, &amp; the particle model explains other features.</td>
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<td>- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.</td>
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<td>- Electromagnetic materials emit electrons when they absorb light of a high-enough frequency.</td>
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<td>- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.</td>
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<td>- Photovoltaic energy includes solar cells, which convert sunlight to electricity. Photovoltaic energy can be used to produce electricity for a home or office, or to power a credit card reader or a calculator. Photovoltaic energy can also be used to power a wind turbine, a solar array, or a solar-powered car.</td>
</tr>
</tbody>
</table>