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, 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.
- 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

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. • 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.	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. Evaluates the procedures and limitations of the experiment, and suggests improvement.	• Use technology to create graphs • Calculate slopes and y-intercepts • Read graphs with a double y-axis • Create line of best fit and determine function of the graph • Identify independent/dependent variable • Create scales for each axis • Label axis with variable and units • Create a title and legendChoose the correct type of graph for the data set.

Lansing School District ©

Yvonne Caamal Canul
Superintendent

Mark Coscarella, Ed.D.
Deputy Superintendent

Kimberly Johnson Ray
Assistant Executive Director for Student Learning

Delsa Chapman
Executive Director for Student Learning

Many thanks to...
the teachers and administrators who helped develop and revise the pacing guides.

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.

Lansing School District ©

Physics • First Quarter
Pacing Guide

Science

Introduction to Your Science Pacing Guide

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 Quicklinks.

Revised 8.2017

Physics Science First Quarter

Unit 1 Motion and Forces

I CAN Statements

- ☐ **I CAN** design and conduct an investigation to determine the relationship between force, mass, and acceleration.
- ☐ **I CAN** apply Newton's 2nd law of motion to solve a variety of real-world problems.

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. Datacould 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.

- ☐ **I CAN** use Newton's Law of Gravity to predict the changes in the gravitational force between two objects when the mass of the objects or distance between objects changes.

Standard HS PS2.4

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 $F_g = G\frac{m_1 m_2}{d^2}$ *only predicts an attractive force because mass is always positive.*

Disciplinary Core Ideas

- Newton's second law accurately predicts changes in the motion of macroscopic objects.
- 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.

Unit 2 Momentum and Impulse

- ☐ **I CAN** support the claim that the total momentum in a system of objects is conserved when there is no external force on the system.

Standard HS PS2.2

Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

Clarification: Compare the momentum of objects when given information about mass and velocity of objects. Use the conservation of momentum to predict the speed of objects after a collision or explosion.

- ☐ **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.

Standard HS PS2.3, HS ETS1.2

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

- 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.

- 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.

Unit 3 Energy

- ☐ **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 acannot be created or destroyed, it only trasforms from one form to another.

Standards HS PS3.1, 3.2

Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Clarification: Calculate gravitational potential energy and kinetic energy of objects and determine changes in the amount of potential and kinetic energy of an object while it is in the air or rolls down an incline. Determine how much energy of an object, such as a falling ball, is transferred into other forms of energy such as thermal energy and sound when it interacts with its surroundings. Describe the energy transformations in devices that convert one form of energy into other forms. (e.g. car, windmill, flashlight).

PS3.2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

Clarification: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.

Disciplinary Core Ideas HS PS3.1

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between.*Additional

- ☐ **I CAN** design, build, and modify a device that works within given constraints to convert one form of energy into another form of energy.

Standard HS PS3.3

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Clarification: Examples of devices built that transfer energy include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and motors or generators.

I CAN Statement

- ☐ **I CAN** analyze a major global challege and offer solutions based on societal needs and wants.

Standard HS ETS1.1

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Clarification: A major global challenge that could be addressed in this course is utilizing renewable energy sources that minimize pollution such as wind turbines and solar cells.

Disciplinary Core Ideas

- 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 fields moves across space.
- See HS.PS.3.1

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.
Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

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.	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. Evaluates the procedures and limitations of the experiment, and suggests improvement.	• Use technology to create graphs • Calculate slopes and y-intercepts • Read graphs with a double y-axis • Create line of best fit and determine function of the graph • Identify independent/dependent variable • Create scales for each axis • Label axis with variable and units

Lansing School District ©

Yvonne Caamal Canul
Superintendent

Mark Coscarella, Ed.D.
Deputy Superintendent

Kimberly Johnson Ray
Assistant Executive Director for Student Learning

Delsa Chapman
Executive Director for Student Learning

Many thanks to...
the teachers and administrators who helped develop and revise the pacing guides.

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.

Lansing School District ©

DRAFT

Physics • Second Quarter

Pacing Guide

Science

Introduction to Your Science Pacing Guide

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 Quicklinks.

Revised 8.2017

Physics Science Second Quarter

Unit 4 Waves			Unit 5 Electricity and Magnetism	
I CAN Statements				
☐ **I CAN** use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	☐ **I CAN** 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.	☐ **I CAN** describe advantages and disadvantages of using digital transmission and storage of information. ☐ **I CAN** explain how some devices use the principles of wave behavior to transmit information and energy.	☐ **I CAN** use Coulomb's ($F = k\frac{q_1 q_2}{d^2}$) law to calculate the electrostatic force between two charged objects. ☐ **I CAN** develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	☐ **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.
Standard HS PS4.1	**Standard HS PS4.3**	**Standards HS PS4.2, PS4.5**	**Standards HS PS2.4, PS3.5**	**Standard HS PS2.5**
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. *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).*	**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.** *Clarification: For wave and particle models, emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of phenomena could include resonance, interference, refraction, diffraction, and photoelectric effect.*	**Evaluate questions about the advantages of using a digital transmission and storage of information.** *Clarification: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include the issue of easy deletion,security, and theft.* **Communicate technical information about how some technological 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.*	**Use mathematical representations of Coulomb's Law to describe and predict electrostatic forces between objects. PS2.4** **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. PS3.5** *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 Describe with words and pictures the type of force (repulsive or attractive) between two charged objects or two magnets. Pictures could be a sketch of the electric field or magnetic field between two like charges or poles and between two unlike charges and poles.*	**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.*
Disciplinary Core Ideas			**Disciplinary Core Ideas**	
▸ 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.	▸ 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. ▸ 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, & the particle model explains othe features.	▸ 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. ▸ Photoelectric materials emit electrons when they absorb light of a high-enough frequency. ▸ 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.	▸ 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. ▸ When two objects interacting through a field change relative position, the energy stored in the field is changed.	▸ 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. ▸ "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.