ARKANSAS
K-12 SCIENCE STANDARDS
EDUCATION FOR A NEW GENERATION

Astronomy

2016

Table of Contents

Arkansas K-12 Science Standards Overview 2
How to Read 5
Astronomy Course Learning Progression Chart 6
Astronomy Course Overview 7
Astronomy Course Topics Overview 8
Topic One: Observational Astronomy 10
Topic Two: Early History of Astronomy 13
Topic Three: Gravitation 15
Topic Four: Formation of the Solar System 18
Topic Five: The Earth, Moon, Sun System 21
Topic Six: Electromagnetic Radiation and Matter 24
Topic Seven: Stellar Evolution 27
Topic Eight: Cosmology 30
Contributors 33

Notes:

1. Student Performance Expectations (PEs) may be taught in any sequence or grouping within a grade level. Several PEs are described as being "partially addressed in this course" because the same PE is revisited in a subsequent course during which that PE is fully addressed.
2. An asterisk (*) indicates an engineering connection to a practice, core idea, or crosscutting concept.
3. The Clarification Statements are examples and additional guidance for the instructor. **AR** indicates Arkansas-specific Clarification Statements.
4. The Assessment Boundaries delineate content that may be taught but not assessed in large-scale assessments. **AR** indicates Arkansas-specific Assessment Boundaries.
5. The section entitled "foundation boxes" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.
6. The examples given (e.g.,) are suggestions for the instructor.
7. Throughout this document, connections are provided to the nature of science as defined by *A Framework for K-12 Science Education* (NRC 2012).
8. Throughout this document, connections are provided to Engineering, Technology, and Applications of Science as defined by *A Framework for K-12 Science Education* (NRC 2012).

9. Each set of PEs lists connections to other disciplinary core ideas (DCIs) within the Arkansas K-12 Science Standards and to the Arkansas English Language Arts Standards, Arkansas Disciplinary Literacy Standards, and the Arkansas Mathematics Standards.

Arkansas K-12 Science Standards Overview

The Arkansas K-12 Science Standards are based on *A Framework for K-12 Science Education* (NRC 2012) and are meant to reflect a new vision for science education. The following conceptual shifts reflect what is new about these science standards. The Arkansas K-12 Science Standards

- reflect science as it is practiced and experienced in the real world,
- build logically from Kindergarten through Grade 12,
- focus on deeper understanding as well as application of content,
- integrate practices, crosscutting concepts, and core ideas, and
- make explicit connections to literacy and math.

As part of teaching the *Arkansas K-12 Science Standards*, it will be important to instruct and guide students in adopting appropriate safety precautions for their student-directed science investigations. Reducing risk and preventing accidents in science classrooms begin with planning. There are four recommended steps in carrying out a hazard and risk assessment for any planned lab investigation.

1) Identify all hazards. Hazards may be physical, chemical, health, or environmental.
2) Evaluate the type of risk associated with each hazard.
3) Write the procedure and all necessary safety precautions in such a way as to eliminate or reduce the risk associated with each hazard.
4) Prepare for any emergency that might arise in spite of all of the required safety precautions.

According to Arkansas Code Annotated § 6-10-113 (2012) for eye protection, every student and teacher in public schools participating in any chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids is required to wear industrial-quality eye protective devices (eye goggles) at all times while participating in science investigations.

The Arkansas K-12 Science Standards outline the knowledge and science and engineering practices that all students should learn by the end of high school. The standards are three-dimensional because each student performance expectation engages students at the nexus of the following three dimensions.

- Dimension 1 describes scientific and engineering practices.
- Dimension 2 describes crosscutting concepts, overarching science concepts that apply across science disciplines.
- Dimension 3 describe core ideas in the science disciplines.

The Science and Engineering Practices

The eight practices describe the major practices that scientists use to investigate, build models and theories of the world around them or engineers use as they build and design systems. The practices are essential for all students to learn and are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

The seven crosscutting concepts bridge disciplinary boundaries and unit core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas, and develop a coherent, and scientifically based view of the world. The seven crosscutting concepts are as follows:

1. *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

2. *Cause and effect: Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

4. *Systems and system models.* Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

6. *Structure and function.* The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. *Stability and change.* For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Disciplinary Core Ideas

The Disciplinary Core Ideas describe the content that occurs at each grade or course. The Arkansas K-12 Science Standards focus on a limited number of core ideas in science and engineering both within and across the disciplines and is built on the notion of learning as a developmental progression. The Disciplinary Core Ideas are grouped into the following domains:

- Physical Science (PS)
- Life Science (LS)
- Earth and Space Science (ESS)
- Engineering, Technology and Applications of Science (ETS)

Connections to the Arkansas English Language Arts Standards

Evidence-based reasoning is the foundation of good scientific practice. The Arkansas K-12 Science Standards incorporate reasoning skills used in language arts to help students improve mastery and understanding in all three disciplines. The Arkansas K-8 Science Committee made every effort to align grade-by-grade with the English language arts (ELA) standards so concepts support what students are learning in their entire curriculum.

Connections to specific ELA standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons. The intersections between Arkansas K-12 Science Standards and Arkansas ELA Standards teach students to analyze data, model concepts, and strategically use tools through productive talk and shared activity. Reading in science requires an appreciation of the norms and conventions of the discipline of science, including understanding the nature of evidence used, an attention to precision and detail, and the capacity to make and assess intricate arguments, synthesize complex information, and follow detailed procedures and accounts of events and concepts. These practice-based standards help teachers foster a classroom culture where students think and reason together, connecting around the subject matter and core ideas.

Connections to the Arkansas Disciplinary Literacy Standards

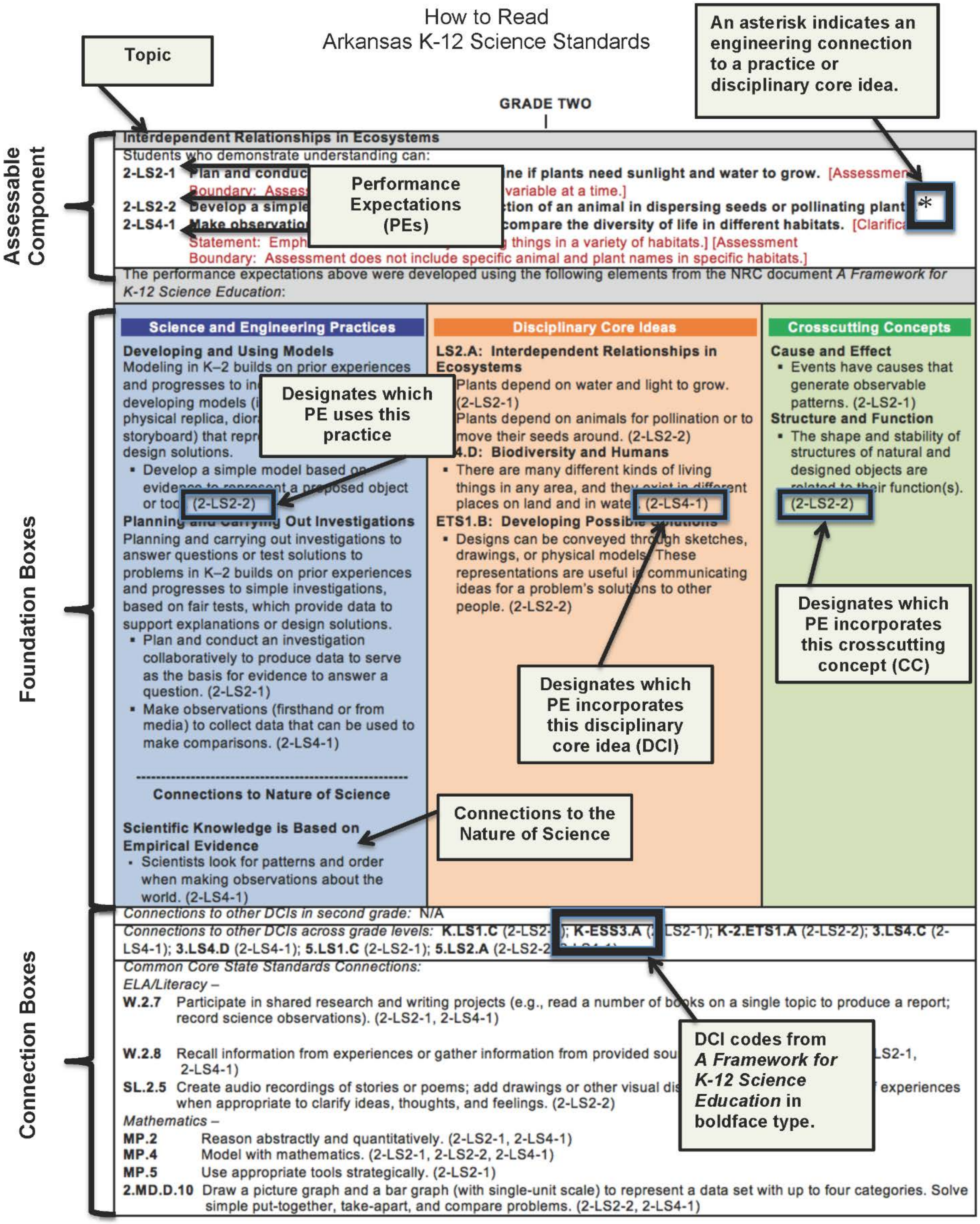
Reading is critical to building knowledge in science. College and career ready reading in science requires an appreciation of the norms and conventions of each discipline, such as the kinds of evidence used in science; an understanding of domain-specific words and phrases; an attention to precise details; and the capacity to evaluate intricate arguments, synthesize complex information, and follow detailed descriptions of events and concepts. When reading scientific and technical texts, students need to be able to gain knowledge from challenging texts that often make extensive use of elaborate diagrams and data to convey information and illustrate concepts. Students must be able to read complex informational texts in science with independence and confidence because the vast majority of reading in college and workforce training programs will be sophisticated nonfiction.

For students, writing is a key means of asserting and defending claims, showing what they know about a science, and conveying what they have experienced, imagined, thought, and felt. To be college and career ready writers, students must take task, purpose, and audience into careful consideration, choosing words, information, structures, and formats deliberately. They need to be able to use technology strategically when creating, refining, and collaborating on writing. They have to become adept at gathering information, evaluating sources, and citing material accurately, reporting finds from their research and analysis of sources in a clear and cogent manner. They must have the flexibility, concentration, and fluency to produce high-quality first-draft text under a tight deadline and the capacity to revisit and make improvements to a piece of writing over multiple drafts when circumstances encourage or require it.

Connections to the Arkansas Mathematics Standards

Science is a quantitative discipline, so it is important for educators to ensure that students' science learning coheres well with their understanding of mathematics. To achieve this alignment, the Arkansas K-12 Science Committee made every effort to ensure that the mathematics standards do not outpace or misalign to the grade-by-grade science standards. Connections to specific math standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

How to Read
Arkansas K-12 Science Standards



Astronomy Learning Progression Chart

Topic 1: Observational Astronomy	Topic 2: Early History of Astronomy	Topic 3: Gravitation	Topic 4: Formation of the Solar System	Topic 5: The Earth, Moon, Sun System	Topic 6: Electromagnetic Radiation and Matter	Topic 7: Organic Chemistry	Topic 8: Cosmology
A-ESS1-1AR A-1-ESS1-2AR A-1-ETS1-2	A-ESS2-1AR A-ESS2-2AR	A-ESS1-4 A-ESS3-1AR A-ESS3-2AR A-3-ETS1-4	A-ESS1-6 A-ESS4-1AR A-ESS4-2AR	A-5-ESS1-1 A-ESS5-1AR A-ESS5-2AR	A-6-ESS1-1 A-ESS6-1AR A-6-ETS1-1	A-7-ESS1-1 A-ESS1-3 A-ESS7-1AR	A-8-ESS1-2 A-ESS8-1AR A-8-ETS1-3

Arkansas Performance Expectations (**AR**)

Astronomy Course Overview

The astronomy course is a science course that continues to develop conceptual understanding of the core ideas, science and engineering practices, and crosscutting concepts in the physical science and Earth and space science. Teachers with a physics, physical science, physical/Earth, life/Earth or physics/math license (including an Earth science endorsement) are able to teach this course. Students will earn one unit of astronomy credit.

Students in astronomy continue to develop fundamental concepts from chemistry, physics, and Earth and space science. The high school performance expectations in astronomy build on the middle school ideas and skills and allow high school students to explain more in-depth phenomena not only in the physical science and Earth and space science. There are eight topics in Astronomy: (1) Observational Astronomy, (2) Early History of Astronomy, (3) Gravitation, (4) Formation of the Solar System, (5) Earth, Moon, and Sun System, (6) Electromagnetic Radiation and Matter, (7) Stellar Evolution, and (8) Cosmology. Students are also expected to demonstrate understanding of several engineering practices, including design and evaluation.

Additionally, it should be noted that the astronomy standards are not intended to be used as curriculum. Instead, the standards are the minimum that students should know and be able to do. Therefore, teachers should continue to differentiate for the needs of their students by adding depth and additional rigor.

Students in astronomy also continue their ability to develop possible solutions for major global problems with engineering design challenges. At the high school level, students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to light the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages:

- **Defining the problem** at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which world population is growing and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.
- **Developing possible solutions** for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected to not only consider a wide range of criteria but to also recognize that criteria needs to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.
- **Improving designs** at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, anticipate possible societal and environmental impacts, and test the validity of their simulations by comparison to the real world.

Astronomy Topics Overview

The performance expectations in **Topic 1: Observational Astronomy** help students formulate answers to the questions:

- How do objects in the sky form patterns of motion?
- How do humans use maps to find their way on the celestial sphere and classify objects seen in the sky according to location, color, magnitude, and other astronomical measures?

Students recognize and classify objects in the sky based on the prior knowledge gained using observational evidence. Students use star maps to find objects in the sky and extrapolate their predicted locations based on various coordinate systems.

The performance expectations in **Topic 2: Early History of Astronomy** help students formulate answers to the questions:

- How did diverse early societies around the world use astronomy to improve their daily lives?
- How did astronomy develop from a primitive superstition into a modern, mathematically-based science?

Students research astronomical models developed by early civilizations. Students use early models of astronomy to accurately and effectively explain the nature of celestial objects and their patterns of motion. Students develop heliocentric models from geocentric models.

The performance expectations in **Topic 3: Gravitation** help students formulate answers to the questions:

- What motivates and controls the various linear and rotational motions of objects in the cosmos?
- How can mathematical models show linear and orbital accelerated motion?
- How does gravity affect the evolution and structure of discrete objects from the smallest asteroid to the largest galactic clusters?

Students develop models to show the effects and motions of rotationally dynamic systems. Students use Newton's laws of gravitation, Pascal's law of pressure, and the principles of thermodynamics to explain planetary structures across a wide class of objects from small moons to Jovian giants and stars.

The performance expectations in **Topic 4: Formation of the Solar System** help students formulate answers to the questions:

- What is the origin of massive objects in the solar system and what is the role of gravity?
- How do astronomers measure objects and distances in space differently than on Earth?

Students use astronomical units, light years, and parsecs. Students use the gravitational model of planetary assembly and evolution to explain the major classes of planets and their internal structures.

The performance expectations in **Topic 5: The Earth, Moon, Sun System** help students formulate answers to the questions:

- What causes eclipses and lunar phases?
- Why do planets have tides and seasons?
- Why do stars shine for millions of years?

Students predict lunar phases based on observational evidence or orbital data. Students explain why lunar and solar eclipses occur at different frequencies and how the interaction of the Earth-Moon-sun system produces these effects. Students predict varying conditions on other planets and moons based on the Earth's seasonal and tidal cycles.

The performance expectations in **Topic 6: Electromagnetic Radiation and Matter** help students formulate answers to the questions:

- What powers the Sun and how does it transmit energy and information out into space?
- How can light be both a wave and a particle?
- How does the dual nature of light impact the use and development of optical technology?

Students use the concept of full-spectrum electromagnetic radiation to explain how stars transmit both energy and information about their structure and composition. Students investigate the dual wave-particle nature of light.

The performance expectations in **Topic 7: Stellar Evolution** help students formulate answers to the questions:

- How does a star's initial mass and composition uniquely determine its stability, lifespan, structure, and final state after cataclysmic star death?
- Where do various elements in the universe originate and what processes account for their production and abundance?

Students model the life cycle and potential long-term stability of a star given initial conditions of mass and composition. Students model the different pathways for heavy and light element synthesis, and relate these ideas to different known classes of stars.

The performance expectations in **Topic 8: Cosmology** help students formulate answers to the questions:

- What evidence do astronomers use to explain the origins of the universe?
- How are galaxies formed?
- How does evidence support both expansion of the universe and the existence of dark matter and dark energy?

Students develop arguments based upon Hubble's data of galactic motion to account for universal expansion. Students construct a model of galactic rotation data demonstrating the existence and effects of dark matter halos around galaxies.

Astronomy Topic 1: Observational Astronomy

Students who demonstrate understanding can:

A-ESS1-1AR

Develop a model using observational evidence that accounts for patterns in the diurnal, seasonal, and annual movements of objects on the celestial sphere. [Clarification Statement: Students record observations of the night sky or use observational data from computer models (Stellarium).]

A-1-ESS1-2AR

Obtain, evaluate, and communicate information gathered from observational evidence, maps, and charts to demonstrate an understanding of the ecliptic patterns, magnitudes, and colors of stars, and the dynamic locations of constellations, asterisms, and planets. [Clarification Statement: Students use both major coordinate systems (Right Ascension/Declination, Altitude/Azimuth). Students account for the independent dynamic motions of the planets, Moon, and sun in contrast with the fixed nature of constellations.

A-1-ETS1-2

Design a solution to a complex real world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. [AR Clarification Statement: A possible real world problem would be to design a way to reduce local light pollution to facilitate the observation of the night sky.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. () **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences 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 world(s). ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. () **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and	**ESS1.A: The Universe and Its Stars** ▪ The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. () **ESS1.B: Earth and the Solar System** ▪ Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(* **PS1.C: Nuclear Processes** ▪ Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. *()* **PS4.C: Information Technologies and Instrumentation**	**Patterns** ▪ Empirical evidence is needed to identify 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. () **Scale, Proportion, and Quantity** ▪ The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. () --------------------------------------- ***Connections to Engineering, Technology, and Applications of Science***

progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. () ▪ 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). () --- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. () ▪ Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. ()	▪ 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, and 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. () **ETS1.A: Defining and Delimiting Engineering Problems** ▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. () ▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. () **ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *()* ▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. () **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be	**Interdependence of Science, Engineering, and Technology** ▪ Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. () **Influence of Engineering, Technology, and Science on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. ()

	approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ()	

Connections:
ELA/Literacy –

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. ()

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *()*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. ()

WHST.9-12.1 Write arguments focused on *discipline-specific content.* ()

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *()*

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *()*

Mathematics –

MP.2 Reason abstractly and quantitatively. ()

MP.4 Model with mathematics. ()

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. ()

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. ()

HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. *()*

HSF-IF.B.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. *()*

HSS-ID.B.6 Represent data on two quantitative variables on a scatter plot, and describe how those variables are related. *()*

Astronomy Topic 2: Early History of Astronomy

Students who demonstrate understanding can:

A-ESS2-1AR

Engage in arguments from evidence about how the development of astronomy in the pre-telescopic age laid the groundwork for modern astronomy. [Clarification Statement: Emphasis is on development and cultural importance of time keeping, navigation, and measurement of the Earth-Moon system.]

A-ESS2-2AR

Construct explanations of how the telescope impacted the evolution of solar system models from geocentric to heliocentric. [Clarification Statement: Emphasis is on the development of the geocentric model by Aristotle and Ptolemy to the development of the Copernican astronomical model which was facilitated by Galileo's telescopic astronomy.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences 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. ()

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Construct an oral and written argument or counter-arguments based on data and evidence. ()

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

Disciplinary Core Ideas

PS4.C: Information Technologies and Instrumentation

- 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, and 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. ()

ETS1.B: Developing Possible Solutions

- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. ()

Crosscutting Concepts

Patterns

- Empirical evidence is needed to identify 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. ()

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ()

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. ()
- Models (e.g., physical, mathematical, computer models) can be used to simulate

sources of evidence consistent with scientific ideas, principles and theories. ▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. () --- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. () ▪ Science disciplines share common rules of evidence used to evaluate explanations about natural systems. () ▪ Science includes the process of coordinating patterns of evidence with current theory. ()		systems and interactions—including energy, matter, and information flows—within and between systems at different scales. ()

Connections:
ELA/Literacy –

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*

RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *()*

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *()*

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *()*

WHST.9-12.1 Write arguments focused on *discipline-specific content.* ()

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. ()

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *()*

Mathematics –

MP.2 Reason abstractly and quantitatively. *()*

MP.4 Model with mathematics.()

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. ()

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. ()

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. ()

Astronomy Topic 3: Gravitation

Students who demonstrate understanding can:

A-ESS1-4

Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [AR Clarification Statement: Emphasis is on applying Kepler's laws of elliptical planetary motion to determine how gravitation affects planetary orbits and orbital velocity.]

A-ESS3-1AR

Use mathematics and computational thinking to demonstrate rotationally dynamic systems and how these structures scale from solar systems to galaxies to bound galactic clusters. [Clarification Statement: Emphasis is on the use of mathematical models of rotationally dynamic systems to apply Newton's laws of gravitation and Kepler's laws of planetary motion.]

A-ESS3-2AR

Construct an explanation of how gravitational forces are influenced by mass, density, and radius and how these forces impact the evolution of planetary structure, surfaces, atmospheres, and rings. [Clarification Statement: Emphasis is on how gravitational forces cause changes in planetary structure, including differentiation of the interior and mediation of ring and moon formation.]

A-3-ETS1-4

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [AR Clarification Statement: Real-world problems could include launching a satellite into geosynchronous orbit or safely landing an orbital vehicle on the surface of a planet or moon. Criteria and constraints could include the mass of the vessel, gravitational conditions on different planets and moons, fuel, materials used, starting position, and velocity vectors.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences 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.

- Create a computational model or simulation of a phenomenon, designed device, process, or system. ()
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. ()
- Use mathematical models and/or computer simulations to predict the

Disciplinary Core Ideas

PS2.A: Forces and Motion

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

PS2.B: Types of Interactions

- 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

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ()

Patterns

- Empirical evidence is needed to identify 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. ()

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the effects of a design solution on systems and/or the interactions between systems. ()

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 knowledge, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. ()
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ()
- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ()
- Evaluate 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 experiences 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 world(s).

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. ()

transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (

PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed. ()

ESS1.B: Earth and the Solar System

- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. ()

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. ()
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. ()

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *()*
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making

scale, proportion, and quantity at which it occurs. ()

Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. ()
- Feedback (negative or positive) can stabilize or destabilize a system. ()

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

- Modern civilization depends on major technological systems. ()
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. ()
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. ()
- Analysis of costs and benefits is a critical aspect of decisions about technology. ()

Connections to Nature of Science

Science is a Human Endeavor

	a persuasive presentation to a client about how a given design will meet his or her needs. () **ETS1.C: Optimizing the Design Solution** ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. ()	▪ Science is a result of human endeavors, imagination, and creativity. () **Science Addresses Questions About the Natural and Material World** ▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. () ▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. () ▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. ()

Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *()*
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. ()
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *()*
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. ()

Mathematics –

MP.2	Reason abstractly and quantitatively. *()*
MP.4	Model with mathematics. ()
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *()*
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. ()
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *()*

Astronomy Topic 4: Formation of the Solar System

Students who demonstrate understanding can:

A-ESS1-6 **Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** [AR Clarification Statement: Emphasis is on evidence found on other planetary, lunar, and meteoric surfaces. Evidence could include detection of water, composition of materials, geological activity, and the evolution of planetary surfaces.]

A-ESS4-1AR **Analyze and interpret data to describe how nebular theory and gravitational collapse result in star and solar system formation with distinct regions characterized by different types of planetary and other bodies.** [Clarification Statement: Emphasis is on the origin and development of Laplace's nebular theory. Emphasis is also on regions of the solar system including the inner and outer solar system and the habitable.]

A-ESS4-2AR **Obtain, evaluate, and communicate information about patterns of size and scale of the solar system, our galaxy, and the universe.** [Clarification Statement: Emphasis is on the differences in solar, galactic, and universal distance and size scales using both qualitative and quantitative tools including scientific notation, appropriate astronomical units, light years, and parsecs.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences 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 computational models in order to make valid and reliable scientific claims. ()

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.

- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ()

Obtaining, Evaluating, and Communicating Information

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ()

ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(*

PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. ()
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ()

Patterns

- Empirical evidence is needed to identify 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. ()

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ()

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. ▪ Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. () ▪ 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). () -- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. () **Scientific Investigations Use a Variety of Methods** ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. () ▪ New technologies advance scientific knowledge. () **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. () ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. ()	positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. () ▪ The availability of energy limits what can occur in any system. ()	

Connections:
ELA/Literacy –

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. ()

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *()*

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*
RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *()*
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (*)*
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. ()
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *()*
Mathematics –	
MP.2	Reason abstractly and quantitatively. (
MP.4	Model with mathematics. ()
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (*)*
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *()*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (

Astronomy Topic 5: The Earth-Moon-Sun System

Students who demonstrate understanding can:

A5-ESS1-1 **Develop a model based on evidence to illustrate the lifespan of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.** [AR Clarification Statement: This PE is partially addressed in this topic. Emphasis is on magnetic processes in the sun and their effects on the solar surface and space weather.]

A-ESS5-1AR **Ask questions about relationships among the Earth, Moon, and sun to clarify the patterns of orbital positions that produce lunar phases and eclipses.** [Clarification Statement: Emphasis is on the positional nature of the lunar phases, including solar and lunar eclipses, and how orbital angles between Earth, Moon, and sun create these effects.]

A-ESS5-2AR **Plan and carry out investigations to demonstrate how relative orbital positions of the Earth, Moon, and sun influence energy and matter flow into and out of a system to create tides and seasons, orbital angles between Earth, Moon, and sun create these effects.** [Clarification Statement: Emphasis is on identifying positional relationships that produce tides on Earth (e.g., spring and neap tides, lunar perigee and apogee). Emphasis is also on positional relationships that produce seasons on Earth and other planets (e.g., axial tilt, perihelion, aphelion).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions. ()

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences 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 world(s).

- Use a model to provide mechanistic accounts of phenomena. ()

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to

Disciplinary Core Ideas

ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *()*

ESS2.A: Earth Materials and Systems

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. ()

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. ()

Crosscutting Concepts

Energy and Matter

- The total amount of energy and matter in closed systems is conserved. ()
- Energy drives the cycling of matter within and between systems. ()

Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. ()

Patterns

- Empirical evidence is needed to identify patterns. ()
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for

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. () --- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. () **Scientific Investigations Use a Variety of Methods** ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. () ▪ New technologies advance scientific knowledge. () **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. () ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. ()	**PS3.A: Definitions of Energy** 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 its various possible forms. (	causality in explanations of phenomena. ()

Connections:
ELA/Literacy –

WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. ()
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *()*
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*
RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *()*

RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *()*
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. ()
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *()*
Mathematics –	
MP.2	Reason abstractly and quantitatively. (
MP.4	Model with mathematics. ()
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *()*
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *()*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (

Astronomy Topic 6: Electromagnetic Radiation and Matter

Students who demonstrate understanding can:

A-6-ESS1-1 Develop a model based on evidence to illustrate the lifespan of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation. [AR Clarification Statement: This PE is partially addressed in this topic. Emphasis is on the role of nuclear fusion in the sun's core producing radiant energy that reaches out into space and carries information about the sun's composition, temperature, and other physical processes.]

A-ESS6-1AR Plan and carry out investigations to demonstrate the dual nature of light as a wave and particle that transmits energy and information about the nature and motion of the matter that emitted it. [Clarification Statement: Emphasis is on the wave and particle nature of light, including the entire range of the electromagnetic spectrum, the use of spectroscopy to investigate the composition of matter, and the use of Doppler shift to determine the relative motion of stars and galaxies.]

A-6-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. [AR Clarification Statement: Possible major global challenges could include disruptions to communication and navigational networks including satellites and land-based communications or use and design of night vision goggles that convert electromagnetic radiation beyond the visible range into useful information.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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 world(s). ▪ Use a model to provide mechanistic accounts of phenomena. () **Planning and Carrying Out Investigations** Planning and carrying out investigations 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	**PS1.A: Structure and Properties of Matter** ▪ A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. () **PS1.B: Chemical Reactions** ▪ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. () **PS3.A: Definitions of Energy** 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 its various possible forms. (	**Energy and Matter** ▪ The total amount of energy and matter in closed systems is conserved. () ▪ Energy drives the cycling of matter within and between systems. () **Systems and System Models** ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. () ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between

of trials, cost, risk, time), and refine the design accordingly. () **Using Mathematics and Computational Thinking** Mathematical and computational thinking in 9-12 builds on K-8 experiences 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. ▪ Create a computational model or simulation of a phenomenon, designed device, process, or system. () ▪ Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. () ▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. () --- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. () **Scientific Investigations Use a Variety of Methods** ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. () ▪ New technologies advance scientific knowledge. () **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. ()	**PS4.B Electromagnetic Radiation** ▪ Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. *()* ▪ 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 many features of electromagnetic radiation, and the particle model explains other features. () ▪ When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. () ▪ Photoelectric materials emit electrons when they absorb light of a high-enough frequency. () **ESS1.A: The Universe and Its Stars** ▪ The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. () **ESS1.B: Earth and the Solar System** ▪ Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(* **ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. ()	systems at different scales. () --- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. ()

▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. ()		

Connections:
ELA/Literacy –

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. ()

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *()*

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*

RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *()*

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *()*

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. ()

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *()*

Mathematics –

MP.2 Reason abstractly and quantitatively. (

MP.4 Model with mathematics. ()

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *()*

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *()*

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (

Astronomy Topic 7: Stellar Evolution

Students who demonstrate understanding can:

A-7-ESS1-1 **Develop a model based on evidence to illustrate the lifespan of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.** [AR Clarification Statement: Emphasis is on developing a model based on evidence to illustrate the lifespan of the sun.]

A-ESS1-3 **Communicate scientific ideas about the way stars, over their lifecycle, produce elements.** [AR Clarification Statement: Emphasis is on the fusion process and the production of elements of atomic #2 (helium) - #26 (iron); elements more massive than iron are produced only during a supernova event at the end of a star's life.]

A-ESS7-1AR **Construct an explanation of how a star's initial mass uniquely determines the conditions that affect stability and factors that control rates of change over its lifetime.** [Clarification Statement: Emphasis is on how initial mass determines the life cycle of a star as described by the Russell-Vogt theorem.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences 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 world(s).

- Use a model to provide mechanistic accounts of phenomena. ()

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.

- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ()

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to

Disciplinary Core Ideas

PS4.B Electromagnetic Radiation

- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. *()*

ESS1.A: The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ()

ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(*

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ()

Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. ()

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ()

Connections to Engineering, Technology, and Applications of Science

evaluating the validity and reliability of the claims, methods, and designs. ▪ Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. () ▪ 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). () -- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. () **Scientific Investigations Use a Variety of Methods** ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. () ▪ New technologies advance scientific knowledge. () **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. () ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. ()		**Influence of Science, Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. ()

Connections:
ELA/Literacy –

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. ()

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *()*

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *()*

RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *()*
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (*)*
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. ()
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *()*

Mathematics –

MP.2	Reason abstractly and quantitatively. (
MP.4	Model with mathematics. ()
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (*)*
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *()*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (

Astronomy Topic 8: Cosmology

Students who demonstrate understanding can:

A-ESS1-2 **Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** [AR Clarification Statement: Emphasis is on dark energy, accelerating cosmic expansion, Hubble's law, and the discovery of the expansion of the universe. Examples of evidence could include cosmic abundances of light elements, the red shift found in galactic spectra, and cosmic microwave background radiation.]

A-ESS8-1AR **Engage in an argument from evidence that the formation of galactic structures depends on a spherical dark matter halo that surrounds a galaxy and supermassive black holes at the center of the galaxy.** [Clarification Standard: Emphasis is placed on galactic structures which influence the evolution of the galaxy and influence the rates of star formation in higher density regions of the galaxy.]

A-8-ETS1-3 **Evaluate a solution to a complex real world problem based upon prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.** [AR Clarification Statement: Use qualitative and quantitative data to analyze a major global challenge for space systems which could include human space travel, terraforming, and colonizing other planets.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). ()

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.

Disciplinary Core Ideas

PS4.B Electromagnetic Radiation

- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. *()*

ESS1.A: The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ()
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. ()
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. ()

ETS1.B: Developing Possible Solutions

Crosscutting Concepts

Energy and Matter

- The total amount of energy and matter in closed systems is conserved. ()
- Energy drives the cycling of matter within and between systems. ()

Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. ()

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. () --- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. () **Scientific Investigations Use a Variety of Methods** ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. () ▪ New technologies advance scientific knowledge. () **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. () ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. ()	▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. ()	New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. ()

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