Chariho Regional School District - Science Curriculum
September, 2016

ASTRONOMY CURRICULUM

Unit 1: Introduction to Astronomy

OVERVIEW

Summary

Students will be introduced to the overarching concept of astronomy. They will look at the history of astronomical exploration and the advancements that have been made in the field since the time of Aristotle. They will learn about the various types of telescopes and how optical principles are used to capture images of the universe. The students will make connections between the advancements in technology and the information available for scientists. Finally, they will gain perspective of the universe by understanding the scale of distances and units of measure.

Content to Be Learned

- Major findings and contributions of the ancient and modern astronomers, including Aristotle, Aristarchus, Ptolemy, Copernicus, Galileo, Kepler, Brahe and others.
- Properties, similarities, and differences between optical, radio and x-ray telescopes, how telescopes are used to photograph the universe, and how they are used in satellites.
- Explore Optics, the branch of physics that deals with properties of light, including reflection and refraction of light. Most importantly at this point, understand how light is used in telescopes to create images.
- Age and scale of the universe- understand how to measure large distances and large time scales, and what units of measure are used in the process.
- Parallax is the apparent displacement of a close object compared to the displacement to a background object and can be used to note the relative distance of stars to one another and to earth.

Practices

- Engaging in argument from evidence.
- Obtaining, evaluating, and communicating information.

Crosscutting Concepts

- Scale, proportion and quantity.
- Cause and effect.

Essential Questions

- Historically, how has the field of astronomy changed over the course of human existence?
- What is the universe and what is earth's place in it?

- How does technology help expand our knowledge of the universe?
- How does light travel through lenses and how are lenses used in a telescope to create an image?

Next Generation Science Standards

Students who demonstrate understanding can:

HS-PS4-1. **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] *[Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]*

The performance expectation above was 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
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 or design solutions to describe and/or support claims and/or explanations.	**PS4.A: Wave Properties** • 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.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-band:
HS.ESS2.A

Articulation of DCIs across grade-bands:
MS.PS4.A ; **MS.PS4.B**

Common Core State Standards Connections:
ELA/Literacy -
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. *(HS-PS4-1)*
Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-PS4-1)
MP.4 Model with mathematics. (HS-PS4-1)
HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1)
HSA-SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. *(HS-PS4-1)*
HSA.CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS4-1)*

Unit 2: Origins of the Universe

OVERVIEW

Summary

Students will investigate the evidence for the Big Bang theory and the origins and expansion of the universe. They will learn about the properties of the electromagnetic spectrum and how objects, like stars or galaxies, give off spectral signatures. These patterns can be used to identify the composition, as well as other characteristics, of that star or galaxy. Students will apply the Doppler Effect to the movement of stars and galaxies, and can then use the information about this movement to support the Big Bang theory.

Content to Be Learned

- The Big Bang theory describes the origin of the universe and is supported by observations of moving celestial objects, including galaxies and stars.

- Galaxies are clusters of stars, gases and other celestial debris and exist in various forms. Galaxies are grouped in clusters.
- The electromagnetic spectrum describes the various forms of radiation that exist in our universe, and each form of radiation can be differentiated based on wavelength, frequency and speed.
- Each different wavelength of electromagnetic radiation has a unique signature, and is based on the composition of the object emitting that radiation.
- Spectroscopy is the branch of science that measures spectra produced when matter emits electromagnetic radiation. Different elements, stars, galaxies, as well as other objects in space have spectra that allow us to identify their composition.
- Using known spectral signatures, the Doppler effect shows how the movement of an object towards or away from the viewpoint can shift the spectra of an object. This shift allows scientists to know what direction an object in space is moving.
- Wein's displacement law and Planck's law can be used to further understand the electromagnetic radiation of an object in space.

Practices

- Constructing explanations and designing solutions.
- Engaging in argument from evidence.

Crosscutting Concepts

- System and system models.
- Energy and matter.

Essential Questions

- How can information about light spectra, motion of galaxies, and composition of matter in the universe support the Big Bang theory?
- How does the Big Bang theory explain the origins and expansion of our universe?
- How can the movement of distant objects in space be observed from earth?

Next Generation Science Standards

HS-ESS1-2 Earth's Place in the Universe

Students who demonstrate understanding can:

HS-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.** [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

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

Science and Engineering Practices

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.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, 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.

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.

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.
- 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.

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. *(secondary)*

Crosscutting Concepts

Energy and Matter

- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems.

Connections to Engineering, Technology, and Applications of Science

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.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
- Science assumes the universe is a vast single system in which basic laws are consistent.

Connections to other DCIs in this grade-band:
HS.PS1.A ; HS.PS1.C ; HS.PS3.A ; HS.PS3.B ; HS.PS4.A

Articulation of DCIs across grade-bands:
MS.PS1.A ; MS.PS4.B ; MS.ESS1.A

Common Core State Standards 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. *(HS-ESS1-2)*
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-2)

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS1-2)
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. (HS-ESS1-2)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS1-2)*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-2)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. *(HS-ESS1-2)*
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-ESS1-2)*
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-ESS1-2)*

Students who demonstrate understanding can:

HS-PS4-3. **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 Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary: Assessment does not include using quantum theory.*]

The performance expectation above was 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
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 worlds. Arguments may also come from current scientific or historical episodes in science. • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - - - - - - - - - - ***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.	**PS4.A: Wave Properties** • [From the 3–5 grade band endpoints] 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. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) **PS4.B: Electromagnetic Radiation** • 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.	**Systems and System 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 systems at different scales.

Connections to other DCIs in this grade-band:
HS.PS3.D ; **HS.ESS1.A** ; **HS.ESS2.D**

Articulation of DCIs across grade-bands:
MS.PS4.B

Common Core State Standards Connections:
ELA/Literacy -

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-3)
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. *(HS-PS4-3)*
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. (HS-PS4-3)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS4-3)
HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. *(HS-PS4-3)*
HSA-SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. *(HS-PS4-3)*
HSA.CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS4-3)*

Unit 3: Stars

OVERVIEW

Summary

Students will focus on the formation of, life cycle and death of a star and will compare this series of events for different types of stars. To do this, student will learn about the structure and composition of stars, and how different characteristics can be measured by astronomers on earth. They will learn to identify a star in various stages of its life, and will be able to classify main sequence stars into spectral classes. They will learn about nuclear fusion that occurs inside a star, where the fuel comes from and what happens to the products of those reactions. They will communicate how a star, over its lifetime, produces elements. Finally, they will analyze data on the brightness/color and temperature of stars to then identify their stage of life, using the Hertzsprung-Russell diagram.

Content to Be Learned

- The structure and composition of a star are used to define and categorize it.
- Different types of stars follow similar, yet different, life cycle patterns.
- The life cycle of a star is primarily based on the size of the protostar.
- Stars all begin from dust, and the formation of a star will follow a series of events.
- Nuclear reactions within stars create the radiation emitted and are fueled by hydrogen and/or helium, depending of the life stage of the star.
- A star's characteristics, such as parallax, luminosity, apparent and absolute brightness (magnitude), size, and temperature, can be measured.
- The Hertzsprung-Russell diagram is a useful tool for analyzing data on star temperature, brightness and color and is used to classify stars.
- A binary star system is one where two stars orbit each other where the center of mass is not located within either star.
- Main sequence stars can be categorized into 7 different spectral classes (O, B, A, F, G, K, and M) based on common properties, including temperature, color, mass, luminosity, and life span.

Practices

- Obtaining, evaluating, and communicating information.
- Using mathematics and computational thinking.
- Analyzing and interpreting data.

Crosscutting Concepts

- Stability and change.
- Energy and matter.

Essential Questions

- How does the size and composition of a star influence the path that it takes during its lifetime?
- How does a star form from dust and gas in the universe?
- How does nuclear fusion inside a star work and how does the presence or absence of fuel move a star from one phase of its life into the next?
- How can the H-R diagram provide scientists with information about the category, temperature or brightness of a star?
- How can various characteristics of a star be measured by astronomers?

Next Generation Science Standards

HS-ESS1-3 Earth's Place in the Universe

Students who demonstrate understanding can:

HS-ESS1-3. **Communicate scientific ideas about the way stars, over their life cycle, produce elements.** [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [*Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.*]

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

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
- Communicate scientific 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).

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.
- 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.

Crosscutting Concepts

Energy and Matter
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Connections to other DCIs in this grade-band:
HS.PS1.A ; **HS.PS1.C**
Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.ESS1.A**
Common Core State Standards Connections:
ELA/Literacy -

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-ESS1-3)*

SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. *(HS-ESS1-3)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-ESS1-3)

HS-PS1-7 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-7. **Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [*Assessment Boundary: Assessment does not include complex chemical reactions.*]

The performance expectation above was 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 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 support claims.

Disciplinary Core Ideas

PS1.B: Chemical Reactions
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Crosscutting Concepts

Energy and Matter
- The total amount of energy and matter in closed systems is conserved.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes the universe is a vast single system in which basic laws are consistent.

Connections to other DCIs in this grade-band:
HS.LS1.C ; **HS.LS2.B** ; **HS.PS3.B**
Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.LS1.C** ; **MS.LS2.B** ; **MS.ESS2.A**
Common Core State Standards Connections:
Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS1-7)

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. (HS-PS1-7)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS1-7)*

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-7)*

Unit 4: Objects in Space

OVERVIEW

Summary

Students will understand the different designations for objects in space. They will learn what defines a planet, and what differentiates it from a dwarf planet. Similarly, they will classify objects as either comets, meteors or asteroids, and will further classify meteors as meteoroids and meteorites. They will use data from asteroid hits on the moon and other planet surfaces to draw conclusions about the formation of the solar system and formation of the earth, and early earth history. Finally, the students will explore how objects impact surfaces, specifically focusing on craters on the surface of the earth and moon, and Mercury.

Content to Be Learned

- A planet is a celestial body that has a predictable orbit around a star. They can be rocky, icy or gassy.
- Exoplanets are celestial bodies that orbit a star other than our sun. Thousands have been discovered using mainly NASA's Kepler telescope.
- Comets, meteors, meteorites, meteoroids, and asteroids are smaller pieces of rock or ice that are not part of a planet.
- Comets, meteors, meteorites, meteoroids, and asteroids can give information about the origins of our solar system, the origins of life, and earth's formation and early history.
- A binary asteroid is a system of two asteroids orbiting a barycenter.
- Craters are depressions on a planet or moon surface caused by the impact of a smaller body with the surface. Their size and shape vary and are due to the size of the impacting body, the speed of collision, and angle of collision.

Practices

- Constructing explanations and designing solutions.

Crosscutting Concepts

- Stability and change.

Essential Questions

- Why did the asteroid belt between Mars and Jupiter not form into a planet?
- Do we have the technology to change the path of an asteroid?
- What is the difference between asteroids, comets, and meteors?
- Why is it believed that comets are derived from the Oort cloud?
- How often do Near Earth Objects enter earth's atmosphere? What happens to them as they travel through the atmosphere?
- What evidence from meteorites and the surfaces of the moon and other planets give us information about the formation of the earth and its early history?
- How can observations of cratering be used to estimate the age of a body's surface?

Next Generation Science Standards

HS-ESS1-6 Earth's Place in the Universe

Students who demonstrate understanding can:

HS-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. [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

The performance expectation above was 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. - *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.	**ESS1.C: The History of Planet Earth** • Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. **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. *(secondary)*	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.

Connections to other DCIs in this grade-band:
HS.PS2.A ; HS.PS2.B
Articulation of DCIs across grade-bands:
MS.PS2.B ; MS.ESS1.B ; MS.ESS1.C ; MS.ESS2.A ; MS.ESS2.B
Common Core State Standards 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. *(HS-ESS1-6)*
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. (HS-ESS1-6)
WHST.9-12.1	Write arguments focused on *discipline-specific content.* (HS-ESS1-6)

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS1-6)
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. (HS-ESS1-6)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS1-6)*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-6)
HSF-IF.B.5	Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. *(HS-ESS1-6)*
HSS-ID.B.6	Represent data on two quantitative variables on a scatter plot, and describe how those variables are related. *(HS-ESS1-6)*

Unit 5: The Solar System

OVERVIEW

Summary

Students will apply mathematical concepts to astronomy in order to calculate various orbits. They will use Kepler's laws to investigate the elliptical nature of planetary orbits and predict the movement of the planets from available empirical data, just as Kepler did. They will review Newton's laws and apply them to the study of the solar system and use them to support Kepler's work with physics. They will conduct a brief inventory of the planets, noting similarities among the Terrestrial planets, and the Jovian planets, and differences between the two groups. They will learn about the various features of moons and rings of the planets. Finally, they will learn about the differences between a planet and a dwarf planet, and debate the current classification of Pluto and Ceres as dwarf planets.

Content to Be Learned

- Orbits of planets in the solar system have varying eccentricities based on the distance between the two focal points of the ellipse.
- Orbits of the individual planets can be tracked and measured, and retrograde motion can be explained based on the regular patterns of the orbits.
- Kepler's three laws define the shapes of the planetary orbits and make definite, testable predictions about the movement of the planets.
- Newton's laws explain the physics that underlies Kepler's laws. Specifically, his Law of Gravity explains how the attraction between the sun and the planets is responsible for the orbits of said planets.
- Formation of the solar system was likely due to the Condensation Theory which follows that the planets were formed from a process of dust condensation, accretion and fragmentation.
- The inner and outer planets are separated by the asteroid belt and among the Terrestrial and Jovian planets, there are many similarities. Each planet has unique characteristics.
- Dwarf planets are planets and exoplanets that do not have clear orbits around a star. They include Pluto and Ceres in our solar system.
- The Asteroid belt lies between Mars and Jupiter and the Kuiper belt lies outside of Neptune's path.
- Most planets have moons, each that have their own unique characteristics.

Practices

- Using mathematical and computational thinking.
- Analyzing and interpreting data.

Crosscutting Concepts

- Cause and effect.
- Scale, proportion and quantity.

Essential Questions

- How can Kepler's laws predict the movement of a planet and the ellipse upon which the planet orbits?
- What modifications were made by Newton to Kepler's laws?
- What are the major differences between the Terrestrial and Jovian planets?
- What characteristics of a celestial body are needed in order to classify it as a planet vs a dwarf planet?
- How does our current understanding of the formation of the solar system build upon previous knowledge? How do scientists think the solar system was formed?

Next Generation Science Standards

HS-ESS1-4 Earth's Place in the Universe

Students who demonstrate understanding can:

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [*Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.*]

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

Science and Engineering Practices

Using Mathematical 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.

- Use mathematical or computational representations of phenomena to describe explanations.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Scale, Proportion, and Quantity

- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

- -

Connections to Engineering, Technology, and Applications of Science

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.

Connections to other DCIs in this grade-band:
HS.PS2.B
Articulation of DCIs across grade-bands:
MS.PS2.A ; **MS.PS2.B** ; **MS.ESS1.A** ; **MS.ESS1.B**
Common Core State Standards Connections:
Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS1-4)
MP.4	Model with mathematics. (HS-ESS1-4)
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. (HS-ESS1-4)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-4)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-4)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-4)
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-ESS1-4)*
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-ESS1-4)*

Students who demonstrate understanding can: **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 Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]
The performance expectation above was 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
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. - - - - - - - - - - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena.	**PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-level:
HS.PS3.C ; HS.ESS1.A ; HS.ESS1.C ; H.ESS2.C

Articulation of DCIs across grade-bands:
MS.PS2.A ; MS.PS3.C

Common Core State Standards 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. *(HS-PS2-1)*
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. (HS-PS2-1)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS2-1)*
Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-PS2-1)
MP.4	Model with mathematics. (HS-PS2-1)
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. (HS-PS2-1)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1)
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1)
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-1)*
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-1)*
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. *(HS-PS2-1)*
HSS-IS.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)*

Unit 6: The Sun-Moon-Earth System

OVERVIEW

Summary

Students will finish the course by focusing on the interactions of the earth with the moon and sun. They will review nuclear fusion and discuss its role in defining characteristics of the sun. They will learn about the various dynamic layers of the sun, and how the atomic interactions vary from layer to layer. They will observe surface dynamics of the sun, including sunspots, flares and other features, and understand how the fluctuations on the sun have interesting and unique effects on earth. They will review surface features of the moon and will investigate the exploration of the moon that has occurred. Students will track moon phases in the night sky and understand why there are changes to what we see every night. They will also look at how the positioning of the earth, moon and sun can result in solar and lunar eclipses. Finally, they will also discuss how the moon influences the tides on earth, and, along with the sun, how those changes can be seen on a daily and monthly scale.

Content to Be Learned

- Our sun is unique in its relationship with earth and allows for life to exist.
- The sun's structure consists of the corona, photosphere, chromosphere, transition zone, convection zone, radiation zone and the core, each with their own properties and characteristics.
- Nuclear fusion occurs within the sun in which a reaction converts hydrogen into helium and releases energy, which makes its way into space.
- The sun is an active star, and its sunspots, solar winds, magnetism, prominences, flares, and other features all contribute to the dynamic workings of the sun.
- Moon structures include craters, lava fields ("maria"), and highlands. The surface closer to earth varies greatly from the surface that faces away from earth.
- The synchronous orbit of the moon is due to the gravitational interactions between the earth and the moon.
- Phases of the moon show the regular patterns in the amount of the lit moon that can be seen from earth.
- Exploration of the moon, both by telescope and by astronauts, have given us a rich history and new data from which many scientific areas have been expanded upon. The history of man's fascination with the moon is an important part of our cultural history as a country.
- Eclipses, both solar and lunar, are due to the relative motion and positioning of the sun, earth and moon.
- Tides on earth are caused by the combined forces of the sun and moon acting on the surface of the earth, on various time scales. High and low tides are due to the movement of the moon around the earth, and spring and neap tides are due to the combined forces of the sun and moon and their relative positions around the earth.

Practices

- Developing and using models.
- Constructing explanations and designing solutions.
- Analyzing and interpreting data.

Crosscutting Concepts

- Structure and function.
- Scale, proportion and quantity.
- Energy and matter.

Essential Questions

- How do the characteristics of the moon compare with those of earth? What is the root cause(s) of those differences?
- How is the moon's rotation influenced by its orbit around earth?
- What data do astronomers use to piece together the story of the moon's formation and evolution?
- What do the characteristics of the sun's outer layers tell us about the sun's surface temperature and

composition?
- What is the nature of the sun's magnetic field and what is its influence on various types of solar activity?
- What is the process by which energy is produced in the sun's interior?
- What is the difference between a sidereal and a synodic month?
- How do the relative motions of the earth, the sun and the moon lead to solar and lunar eclipses?

Next Generation Science Standards

HS-ESS1-1 Earth's Place in the Universe

Students who demonstrate understanding can:

HS-ESS1-1. **Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [*Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]*

The performance expectation above was 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). • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS1.A: The Universe and Its Stars** • The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. **PS3.D: Energy in Chemical Processes and Everyday Life** • Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. *(secondary)*	**Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Connections to other DCIs in this grade-band:
HS.PS1.C ; **HS.PS3.A**
Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS4.B** ; **MS.ESS1.A** ; **MS.ESS2.A** ; **MS.ESS2.D**
Common Core State Standards 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. *(HS-ESS1-1)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS1-1)
MP.4	Model with mathematics. (HS-ESS1-1)
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. (HS-ESS1-1)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. *(HS-ESS1-1)*
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-ESS1-1)*
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-ESS1-1)*

HS-PS1-8 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-8. **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

The performance expectation above was 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 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 a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.	**Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Connections to other DCIs in this grade-band:
HS.PS3.A ; **HS.PS3.B** ; **HS.PS3.C** ; **HS.PS3.D** ; **HS.ESS1.A** ; **HS.ESS1.C** ; **HS.ESS3.A** ; **HS.ESS3.C**

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.ESS2.A**

Common Core State Standards Connections:
Mathematics -

MP.4	Model with mathematics. *(HS-PS1-8)*
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. (HS-PS1-8)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-8)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-8)*