West Windsor-Plainsboro Regional School District
Course Title: Descriptive Astronomy
Grades: 11 - 12

The Mission of the West Windsor-Plainsboro Science Department

Our mission is to cultivate science learners who have the foundational knowledge to make ethical, scientifically literate decisions and the ability to apply scientific practices in order to contribute to the needs of society and a changing world.

- **Vision**

  We envision a K-12 science experience that supports and challenges every student in their science learning journey. We will:
    - *Capitalize on diversity by reaching and exciting students at all levels and interests by differentiating learning within classrooms and by offering a robust program of studies.*
    - *Emphasize authentic science and engineering practices and leverage the interdisciplinary nature of science with arts, technology, math, reading, and writing.*
    - *Integrate scientific knowledge and 21st century competencies to prepare students to make informed decisions and take action to address real world problems.*

Unit 0 – General Lab Safety and Procedures	
Content Area: Science	
Course & Grade Level: Descriptive Astronomy, 11-12	
Summary and Rationale	
This unit introduces students to basic laboratory techniques, safety standards and data analysis methods. Students will learn proper handling, storage, and/or disposal of lab equipment such as telescopes, computers, cameras, and more, as well as an overview of lab facilities.	
Recommended Pacing	
~3 days	
New Jersey Student Learning Standards for Science	
Standard: NGSS	
CPI #	**Cumulative Progress Indicator (CPI)**
	Demonstrate how to use scientific tools and instruments with respect for student safety.
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. [Clarification Statement: Emphasis is placed on safety in the laboratory as well as the environmental impact of our actions.]
Instructional Focus	
Unit Enduring Understandings:	
• Clear, accurate, organized and concise communication is essential for scientists. • Safety in the science laboratory requires using your common sense at all times! • Different systems of measurement are used for different purposes. • Correct selection of measurement instruments and measurement language will ensure accurate results.	
Unit Essential Questions:	
• Are all laboratory activities approached in the same manner? • Why do we need to practice safe habits in the science laboratory? • Is it necessary to use a common set of measurement units? Why or why not? • Are all students in my class equally safety conscious in the science lab setting?	
Objectives	
Students will know: • Identify common lab equipment • Identify the lab book setup and guidelines **Students will be able to:** • Demonstrate safe behavior in the laboratory. • Properly use common laboratory equipment. • Demonstrate proficient setup and data collection/analysis in lab notebook (e.g. astronomical logs). • Demonstrate proper graphical analysis techniques; including preparing and reading graphs, identifying the dependent and independent variables, interpolating and extrapolating data.	
Evidence of Learning	
• Demonstrate personal safety while using glassware, lifting and managing heavy objects, and handling other equipment.	
Resources	
WWP Policy: 7420 (pg. 335, 7432)	

Unit 1 – Earth-Based Astronomy	
Content Area: Science	
Course & Grade Level: Descriptive Astronomy, 11-12	
Summary and Rationale	
In this unit students will study astronomy from an historical and technological perspective. The advancement of scientific understanding often depends on the development of new technology. Ancient sky observers were limited to understanding the Universe by what they could observe with the naked eye. Students will study how ancient and more modern cultures built structures to help them model the workings of our solar system. For example, a reference to important astronomical work by the Egyptians (rising of Sirius correlating to the yearly flooding of the Nile.) Students will also study how direct observations of the sky can provide a powerful understanding of the workings of our solar system. Students will collect and use data to explain why the Earth experiences seasons. Students will study the underlying science and build a working telescope. Students will use data from computer simulations to observe complex motions in the sky and study how ancient astronomers interpreted this data to model the workings of our solar system. Students will also learn about some of the individuals that made advances in the field, and the influence of various global cultures that either helped them or presented them with adversity. (Examples may include, but are not limited to: Benjamin Banneker; Annie Jump Cannon; Cecilia Payne; Caroline Herschel; Subrahmanyan Chandrasekhar; Meghnad Saha; and others. In doing so, students have the opportunity to identify personal, cultural and/or linguistic connections with these individuals, highlighting the self-awareness and social awareness SEL competencies of the CASEL framework.	
Recommended Pacing	
~35 days	
New Jersey Student Learning Standards for Science	
Standard: NGSS	
CPI #:	**Cumulative Progress Indicator (CPI)**
HS-ETS1-1	**Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
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.]*
HS-PS4-1	**Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.**
HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth systems result in changes in climate. *[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]*

New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).
9.2.12.C.4	Analyze how economic conditions and societal changes influence employment trends and future education.
9.2.12.C.3	Identify transferable career skills and design alternate career plans.
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Ask and refine questions to support uniform energy distribution among the components in a system when two components of different temperature are combined, using specific textual evidence.	
Use a model to describe variations in the flow of energy into and out of Earth systems.	
Conduct short as well as more sustained research projects to determine energy distribution in a system when two components of different temperature are combined.	
Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.	
Synthesize findings from experimental data into a coherent understanding of energy distribution in a system.	
Cite specific textual evidence to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios.	
Mathematics Interdisciplinary Standards	
Use symbols to represent energy distribution in a system when two components of different temperature are combined, and manipulate the representing symbols. Make sense of quantities and relationships in the energy distribution in a system when two components of different temperature are combined.	
Use a mathematical model to describe energy distribution in a system when two components of different temperatures are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.	
Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the properties of water and their effects on Earth materials and surface processes.	
Social Studies Interdisciplinary Standards	
Standard 6.1 U.S. History: American in the World	All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus
Unit Enduring Understandings
• While technological innovations such as the telescope played an important role in our evolving understanding of the universe, much can be discerned about the Universe by simply looking up at the sky. Careful observation of the Sun, Moon and stars can provide useful information about the seasons, tides, weather and various other phenomena that were useful to ancient and modern cultures. In addition, observing the night sky was used by ancient astronomers to model the workings of the solar system and Universe and provided the data necessary to transition from a geocentric model of the solar system to our current heliocentric model. • Astronomy and astronomical observations played an important role in ancient cultures. The ability to predict the length of a day, moon phase and other characteristics of the "heavens" was important enough to justify unprecedented societal effort and sacrifice to produce large scale astronomical "observatories" such as Stonehenge, Machu Picchu, the Moai of the Easter Islands as well as many others. • The discovery that curved glass could be used to magnify images can be traced back to work of ancient Islamic scientists such as al-Kindi and Western philosopher Roger Bacon. The first telescopes, built by spectacle makers in the 1600s, laid the groundwork for an explosion in observations and data at the time. The workings of telescopes is explained by the science of optics. Geometric optics can be used to understand how telescopes work and predict the types of images that various types of lenses will produce when used individually or in combination. • The invention of the telescope has played an important role in our ability to study and understand the workings of the "heavens" and Earth's place in the cosmos. The telescope allowed ancient astronomers to observe bodies orbiting other bodies in the night sky and showed the details of nearby celestial objects with greater detail and focus. The ability to see the Moon with greater detail caused Galileo and others to question the "perfection" of heavenly bodies and laid the groundwork for suggesting that life may exist elsewhere and that the Earth may not be the center of the Solar System.
Unit Essential Questions
• Why were ancient cultures interested in observing the night sky? • How and why did ancient cultures build structures to help them keep track of astronomical events? • Why does the appearance of the night sky change? • What can we tell about the Earth by observing the sky? • Why does the Earth have seasons? • Are astronomers all over the Earth looking at the same night sky? • Why do astronomical objects appear to undergo complex motions? • What are constellations? • Why does the Moon's appearance change during a monthly cycle? • What are tides and how do they relate to the Moon and its cycles? • What are the geocentric and heliocentric models of the solar system? • How do telescopes work?
Objectives
Students will know: • A perspective of Earth's place in the Universe. • How to compare and evaluate various models to explain accepted phenomena. • How to use data to develop models and draw conclusions. • How to use appropriate technology to experience astronomical phenomena first hand. • **T**he components of a telescope and how to assemble them to create a working telescope.

Instructional Focus (cont'd)

Objectives (cont'd):

Students will know (cont'd):

- How to use ray tracing to determine the type of image that a lens produces and whether it will be magnified or reduced, real or virtual.
- Tracking the sun's position in the sky and along the horizon can provide useful information about the seasons.
- How to use shadow length to determine the Earth's diameter
- The moon's movement around the Earth leads to moon phases.
- The moon's gravity causes tides on Earth.
- The axial tilt of the Earth leads to seasons on Earth, rather than Earth's progression in its orbit.
- Constellations represent culturally defined arrangements of stars in the sky.
- The Sun is the center of the Solar System and interacts with other objects through the force of gravity.

Students will be able to:

- Describe the apparent motions of the Moon, Sun, planets and stars using the appropriate physical principles, Laws or models.
- Explain the causes of seasons on Earth.
- Trace the development of astronomical thoughts and theories from earliest times to the present.
- Analyze and interpret data in various forms to determine and support conclusions.

Sample Performance Tasks-Specific for Unit 1: SWBAT:

- Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. **[ESS1.B]**
  The activity "Reasons for Seasons" tracks the apparent size of the Sun at various times of the year. Because of its elliptical orbit the Sun will appear to be different sizes at different times of the year. This activity demonstrates that the common sense explanation for the Reason for the Seasons (i.e. Earth-Sun distance) is not consistent with the actual pattern of distances from the sun (in the Northern Hemisphere). This lays the groundwork for allowing the students to look at the data and process the role of axial tilt in determining sun angle and day-length and their role in the seasons.
- Students will create and use a "starfinder" as a model to track motions of objects in the sky and explain seasonal patterns of stellar objects.
- Students will use knowledge of scale, proportion and quantity to mathematically determine the diameter of the Earth using observational data - shadow length at various cities on the summer solstice.
- Students will use evidence to evaluate the role that solar energy output plays in climate change, paying attention to scale and proportion between the two entities.
  References:
  https://climate.nasa.gov/blog/2910/what-is-the-suns-role-in-climate-change/
  https://www.nasa.gov/mission_pages/sunearth/solar-events-news/Does-the-Solar-Cycle-Affect-Earths-Climate.html
- NGSS Practices: Developing and Using Models; Using mathematics and computational thinking; Engaging in Argument from Evidence
- NGSS Crosscutting Concepts: Patterns; Scale, Proportion and Quantity; Energy and matter: Flows, cycles, and conservation NGSS DCIs: (HS ESS1-4); HS-ESS2-4

Resources

Core Text: Fraknoi, Andrew; Morrison, David; and Wolff, Sideny C., et al. *Astronomy,* Jan 2021 Edition. OpenStax. Print ISBN: 1-938168-28-3. PDF ISBN: 1-947172-24-7
Resources (cont'd)

Unit 2 - Planets and Solar Systems	
Content Area: Science	
Course & Grade Level: Descriptive Astronomy, 11-12	
Summary and Rationale	
In this unit students study the formation and composition of the various bodies in our solar system. Students will learn about Newton's Law of Gravitation and use it to explain the initial formation of the Solar System as well as how bodies in the solar system interact with each other. Students will use data and Kepler's Laws to model planetary motions and justify various theories of our solar system. Students will learn how the Sun and planets form through similar mechanisms, with the important difference being the mass of the Sun and how this leads to thermo-nuclear fusion at its core. Students will learn how the composition and mass of planets lead to the conditions found on its surface. Students will learn to analyze the contributions of incident sun energy and atmospheric composition to determine planetary temperature and climate. Students will do a case study comparison of the terrestrial planets Venus, Earth and Mars to determine why their climates are so dramatically different. Students will use this data to analyze humanity's effect on the Earth's atmosphere and how this has influenced natural cycles of climate.	
Recommended Pacing	
~40 days	
New Jersey Student Learning Standards for Science	
Standard: NGSS	
CPI #:	**Cumulative Progress Indicator (CPI)**
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.]*
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.]*
HS-ESS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
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.]*

New Jersey Student Learning Standards for Science (cont'd)	
Standard: NGSS	
CPI #:	**Cumulative Progress Indicator (CPI)**
HS-ESS2-2	Analyze geoscience data to make the claim that one change to the Earth's surface can create feedbacks that cause changes to other Earth systems. *[Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]*
HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. *[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]*
ESS1.B	Earth and the Solar System- Cyclical changes in the shape of the 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. (secondary to HS-ESS2-4)
HS-ESS3-6	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. *[Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]*

New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).

9.2.12.C.4	Analyze how economic conditions and societal changes influence employment trends and future education.
9.2.12.C.3	Identify transferable career skills and design alternate career plans.
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Use a model to describe variations in the flow of energy into and out of Earth systems.	
Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.	
Synthesize findings from experimental data into a coherent understanding of energy distribution in a system.	
Conduct short as well as more sustained research projects to determine how the properties of water affect Earth materials and surface processes.	
Mathematics Interdisciplinary Standards	
Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.	
Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the properties of water and their effects on Earth materials and surface processes.	
Social Studies Interdisciplinary Standards	
Standard 6.1 U.S. History: American in the World	All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus
Unit Enduring Understandings:

- It was previously thought that Earth was at the center of the universe, but it is now known that the Sun is the central and largest body in the Solar System. The Solar System includes Earth and other planets and their moons as well as other objects such as asteroids and comets. Objects in the Solar System are kept in predictable motion by the force of gravity. Our Solar System formed from a nebular cloud of gas and dust left over from dying stars that formed earlier.
- The Sun, like the other bodies in the solar system, was formed by the opposing actions of gravity and thermal expansion over long periods of time. The end result of this process (planet or star) depends on the relative balance of these forces which is in turn dependent on the mass of the body involved. Large mass objects, like the sun, produce extremely powerful gravitational forces that cause the matter in the core of stars to collapse to the point where smaller atoms fuse together to form larger atoms in a process called nuclear fusion. The loss of mass during nuclear fusion is the source of energy for the sun and powers life on Earth.
- Using various scientific techniques, astronomers have been able to probe the interior of the sun and have determined that the sun contains multiple layers. The layers of the sun are distinguished primarily by how energy is transferred within. Energy transfer through these layers of the sun can cause light from the core to take hundreds of thousands of years to be transmitted from its surface outward to the rest of the solar system.
- The composition and structure of the planets and other bodies in the solar system has been influenced by their mass, location relative to the Sun and local conditions during their formation. The

combination of these factors leads to the formation of two major types of planets in the solar system, terrestrial planets and giant planets. Planets and other bodies can be further modified by collisions and tectonic activity.

Instructional Focus (cont'd)

Unit Enduring Understandings (cont'd):

- The discovery of major bodies beyond the orbit of Pluto led astronomers to formally define the characteristics of a planet. This formal definition included a new category of solar system object, the dwarf planet. Pluto, as well as several other large bodies in the solar system, are now classified as dwarf planets.
- The conditions on the surface of planets in our solar system are influenced by multiple factors including atmospheric composition, distance from the sun and geological activity. The climate on the surface of the Earth is quite different from some otherwise similar planets in the solar system and is influenced by a complex interplay of multiple factors.
- Climate on Earth has and will continue to change over time. However, humankind's technological evolution has caused changes to the composition of our atmosphere and hydrosphere. These changes have caused significant and measurable changes in the Earth's overall temperature and thus its climate.

Unit Essential Questions:

- How and why did the Solar system form?
- What are the different kinds of objects found in the solar system?
- To what extent do the interactions of objects in our Solar System cause observable phenomena?
- Why is it necessary to use models to understand and explain the interactions of objects in the Universe?
- How does the Sun produce the energy that it releases?
- How are bodies within the Solar System categorized?
- What is climate and why does it change here on Earth?
- How has humankind influenced the rate and direction of planetary climate change?
- What can we learn about possible consequences of planetary climate change by looking at our planetary neighbors, Venus and Mars?

Objectives

Students will know:

- The Sun and other objects in the Solar System have formed through similar mechanisms over long periods of time.
- Gravity plays a crucial role in the formation of and interactions between objects in the Solar System.
- Nuclear fusion powers the Sun by converting matter to energy, as described by $E=mc^2$.
- Kepler's laws describe common features of the motions of orbiting objects including their elliptical paths around the Sun
- Orbits may change due to gravitational effects from, or collisions with, other objects in the solar system.
- The characteristics of planets depend on a number of factors, including mass, composition and distance from the sun.
- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other climate changes on Earth and other planets as well.
- Humans have influenced the composition of our atmosphere and have changed the balance of energy flowing in and out of our planet by modifying the greenhouse effect.

- The planets Mars and Venus can provide us a glimpse at how different patterns of energy flow can influence the habitability of planets.

Instructional Focus (cont'd)

Objectives (cont'd)

Students will be able to:

- Describe the formation of the solar system.
- Use Newton's Law of Gravitation to determine how gravity is influenced by mass and distance.
- Explain how the formula $E=mc^2$ accounts for the mass lost by the sun and the energy it releases.
- Use Kepler's laws to describe the relationship between distance from the sun and the period of a planet's orbit.
- Describe the factors that increase or decrease the amount of energy that a planet absorbs or releases.
- Explain how humans have influenced the direction and pace of climate change on Earth.

Sample Performance Tasks-Specific for Unit 2:

- HS-ESS1-4 Use mathematical or computational representations of phenomena to describe explanations such as Kepler's laws to describe common features of the motions of orbiting objects, including their elliptical paths around the sun and predict the effect of a change in one variable on another. [ESS1.B]
- Students will evaluate evidence to investigate the role that orbit shape, axial tilt, and direction of axis play in climate change, paying attention to solar energy input and scale and proportion between the two entities.
  References:
  https://climate.nasa.gov/news/2948/milankovitch-orbital-cycles-and-their-role-in-earths-climate/
  In the classroom, a lesson or series of lessons could study those three effects (periodic change in orbital eccentricity; periodic change in axial tilt; and axial precession). The three effects have long, but fairly-understood, periods, all of which extend beyond the length of time during which we have seen climate change occur. Perhaps in a full class, six groups could be assigned (two to each cause, perhaps somewhat intentionally toward general ability/previous understanding) to one of the orbital changes, and "jigsaw" the whole explanation together as a class (which boils down to: none of these changes in motion explain climate change.)
- NGSS Practices: Developing and Using Models; Using mathematics and computational thinking; Engaging in Argument from Evidence
- NGSS Crosscutting Concepts: Patterns; Scale, Proportion and Quantity; Energy and matter: Flows, cycles, and conservation
- NGSS DCIs: (HS ESS1-4); (HS-ESS2-4)

Resources

Core Text: Fraknoi, Andrew; Morrison, David; and Wolff, Sideny C., et al. *Astronomy,* Jan 2021 Edition. OpenStax. Print ISBN: 1-938168-28-3. PDF ISBN: 1-947172-24-7

Resources (cont'd):

Unit 3 - Stellar Evolution and Classification	
Content Area: Science	
Course & Grade Level: Descriptive Astronomy, 11-12	
Summary and Rationale	
In this unit, students will study stars and their properties. Students will learn the role that a star's mass can play in the course of a star's evolution, along with determining its other properties, like luminosity/magnitude and temperature. Students will also learn the processes by which stars give off light (nuclear fusion) and that the origin of all the heavier elements in the universe, including the atoms that make up their own bodies, is ultimately the stars themselves. Students will be tasked with analyzing data, including graphing, that gives insight into the evolution and classification of stars. Some attention should also be given to the historical context in which these findings were developed.	
Recommended Pacing	
~35 days	
New Jersey Student Learning Standards for Science	
Standard: NGSS	
CPI #:	**Cumulative Progress Indicator (CPI)**
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.]*
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.]
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.]
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
Standard:	
CPI #:	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).

New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills (cont'd)	
Standard:	
CPI #:	**Cumulative Progress Indicator (CPI)**
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).
9.2.12.C.4	Analyze how economic conditions and societal changes influence employment trends and future education.
9.2.12.C.3	Identify transferable career skills and design alternate career plans.
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Draw from and/or cite specific textual evidence to support scientific or other academic claims (e.g. primary source text for current or historical events in the field, etc).	
Pose and refine scientific questions in service of conducting an experiment or research project (e.g. what objects will be studied? How will the experimenter classify observations? etc).	
Integrate and evaluate multiple sources of information presented in diverse formats and media in order to support scientific or other academic claims (e.g. archival/historical text, peer-reviewed technical work, etc).	
Evaluate hypotheses, data, and conclusions, synthesizing evidence from multiple reputable sources and citing specific textual evidence to engage in argument-from-evidence about a scientific or science-related proposal or problem. (e.g. evaluating federal funding for astronomical research; managing energy and mineral resources; etc.)	
Mathematics Interdisciplinary Standards	
Mathematics	Represent scientific claims symbolically and manipulate representative symbols through the use of mathematical models.
Mathematics	Identify important quantities and use mathematical models to analyze relationships, draw conclusions, and make predictions about the behavior of a system.
Mathematics	Choose a level of accuracy appropriate to limitations on measurement when reporting measured quantities (e.g. significant figures, etc).
Mathematics	Define appropriate quantities for the purpose of modeling, and choose and interpret: consistent units of measure; scale and origin of graphs; and data visualization to analyze and support scientific claims (e.g. visual data displays that represent the phases of a star's life via a Hertzsprung-Russell diagram).
Social Studies Interdisciplinary Standards	
Standard 6.1 U.S. History: American in the World	All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus
Unit Enduring Understandings
● Starlight comes from the fusion of atoms inside of stars. ● Observing starlight can give evidence about a star's composition and stage of life. ● A star's life may branch through different paths, determined largely by its original mass.
Unit Essential Questions
● What is starlight? ● Why are some stars brighter than others? ● How are stars formed? Do they "die?" ● Are there types of stars? What are their properties? ● What role does mass have to play in a star's other properties?
Objectives:
Students will know: ● A star is made of mostly hydrogen, with heavier elements at its core. ● All elements that occur naturally have their origin in the core of stars. ● Observing starlight can allow other characteristics, like distance and velocity, to be determined. ● The brightness of stars depends on their properties. ● Relative magnitude tells us about the brightness of the stars, as seen from where we are; absolute magnitude tells us about the brightness of the stars relative only to each other, from a standard distance. ● Stars form through gravity; if enough material is collected into one location, the increased temperature and pressure can reach a threshold where a star can "ignite." ● There are several kinds of stars, including white dwarfs, neutron stars, red giants, pulsars, and more; they can be classified by their properties with systems such as the Harvard system, H-R diagrams, etc. ● The lifespan and major events in a star's life cycle are largely determined by the star's mass. **Students will be able to:** ● Construct and record data. ● Analyze and interpret data to form a conclusion. ● Construct an argument that is grounded in evidence and scientific models.
Sample Performance Tasks-Specific for Unit 3: SWBAT: ● use a model to classify a star's spectral type and stage of life, based on data they either observe themselves or obtain from professional sources. ● 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. ● develop and use a model to examine the changes in a star's density as it progresses through its lifecycle. ● model the relative sizes of stars as they progress through their lifecycle, examining the hydrogen:helium ratio of a star's core as it ages. ● model the scale of energy released by a star's fusion process as compared to the scale of energy released by chemical reactions in everyday life. ● NGSS Practices: Developing and Using Models; Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information ● NGSS Crosscutting Concept: Scale, Proportion, and Quantity; Energy and Matter ● NGSS DCIs: (HS-ESS1-1, HS-PS3-D)
Resources

Core Text: Project Star: Science Teaching Through Its Astronomical Roots, Coyle, et.al., Kendall/Hunt. ISBN 0-7872-6015-0,

Unit 4 - Clusters, Galaxies and the Universe	
Content Area: Science	
Course & Grade Level: Descriptive Astronomy, 11-12	
Summary and Rationale	
In this unit, students will learn about the larger structures in the universe: star clusters, galaxies, and even the universe itself. Students will gain a general understanding of the current best explanations for the origin of the universe, and the competing predictions for the end of the universe and learn to evaluate the evidence that supports these predictions. Students will be asked to grapple with basic cosmological questions that, as yet, may not have completely-settled answers, but that is the fundamental nature of the process of science. It is for this reason we include these topics for study.	
Recommended Pacing	
~35 days	
New Jersey Student Learning Standards for Science	
Standard: NGSS	
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.]*
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.]
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.]
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
Standard:	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).
9.2.12.C.4	Analyze how economic conditions and societal changes influence employment trends and future education.
9.2.12.C.3	Identify transferable career skills and design alternate career plans.

New Jersey Student Learning Standards for English Language Arts Companion Standards	
English/LA	Evaluate the hypotheses, data, analysis, and conclusions in a scientific or technical text (e.g. comparing models of spatial expansion of the Universe under different models of dark energy).
Mathematics Interdisciplinary Standards	
Mathematics	Represent scientific claims symbolically and manipulate representative symbols through the use of mathematical models (e.g. the relationship between frequency and energy of light waves).
Mathematics	Define appropriate quantities for the purpose of modeling, and choose and interpret: consistent units of measure; scale and origin of graphs; and data visualization to analyze and support scientific claims (e.g. visual data displays that represent direction of rotation of a galaxy).
Mathematics	Choose a level of accuracy appropriate to limitations on measurement when reporting measured quantities (e.g. significant figures, etc).
Social Studies Interdisciplinary Standards	
Standard 6.1 U.S. History: American in the World	All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus
Unit Enduring Understandings
• Clusters are large groups of stars bound together by gravity. • There are several types of galaxies; some form simply by mutual gravity, others form by galaxy "collisions." • Galaxies are made up of a large collection of stars. There is a dividing line between star clusters and galaxies. • The universe has several constituents: matter, antimatter, dark matter, and dark energy. ○ We do not have a good understanding of dark matter or dark energy, though they make up the majority of the composition of the universe. ○ We do not understand why there is a relative abundance of matter as compared with a relative absence of antimatter. • The Big Bang model is, at present, our best explanation for the observations we have made about the motion of distant galaxies. • There are several competing predictions about the ultimate fate of the universe; evidence exists that supports each.
Unit Essential Questions
• What is a star cluster? • How do star clusters form? What types of star clusters are there? • What is a galaxy? What is it made of?

Instructional Focus (cont'd)
Unit Essential Questions (cont'd)
● How do galaxies form? What types of galaxies are there? ● Can galaxies evolve? What happens if galaxies collide? ● What is the stuff in the universe made of? ● Is there a shape to the universe? What does it mean for space to have shape? ● Is the shape of the universe changing, with time? Why, or why not? ● Did the universe have a beginning? How do we know? Will the universe have an end? How can we make a prediction?
Objectives
Students will know: ● The proportion of matter, antimatter, dark matter, and dark energy that is currently understood as the composition of the universe. ● The nature of space-time, observed changes in its shape, and explanations of the same. ● The current model for the beginning of the universe (Big Bang model). ● the competing models that predict the "end" of the universe, and the evidence that supports those ideas. **Students will be able to:** ● Correctly describe theoretical ideas in cosmology in appropriate terms to a target audience. ● Evaluate the strength of evidence for competing scientific models. ● Reflect on the uncertain nature of the process of scientific inquiry
Sample Performance Tasks-Specific for Unit 4: SWBAT: ● develop a model based on evidence to illustrate the age of individual stars, galaxies, and the universe itself, and the role nuclear fusion plays in predicting the end of the universe. ● argue from evidence about which of the competing predictions about the end of the universe is most likely. ● NGSS Practices: Developing and Using Models; Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information; Arguing from Evidence ● NGSS Crosscutting Concept: Scale, Proportion, and Quantity; Energy and Matter ● NGSS DCIs: (HS-ESS1-1, HS-PS3-D)
Resources
Core Text: Fraknoi, Andrew; Morrison, David; and Wolff, Sideny C., et al. *Astronomy,* Jan 2021 Edition. OpenStax. Print ISBN: 1-938168-28-3. PDF ISBN: 1-947172-24-7
Resources (cont'd)