HS-ESS1-4

Students who demonstrate understanding can:

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.]*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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.	**ESS1.B: Earth and the Solar System** 6. 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.	**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.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

5.2 Ability to conduct mathematical and/or computational analyses

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

5.2.1 Ability to use the results of computational models (e.g., graphical representation in a simulation) to identify the mathematical and/or computational representations to support a scientific explanation or a design solution

5.2.2 Ability to use computational models (e.g., simulations) to make predictions of a scientific phenomenon

5.2.3 Ability to use the results of computational models (e.g., simulations) to identify patterns in natural and/or design worlds

Disciplinary Core Idea Assessment Targets

ESS1.B.6a Represent, identify, and describe a mathematical and/or computational model of orbital motion including the trajectories of orbiting bodies (including planets, moons, or human-made spacecraft) with the depiction of the revolving body's eccentricity, e=f/d, where f is the distance between foci of an ellipse, and d is the ellipse's major axis length (Kepler's first law of planetary motion)

ESS1.B.6b Use Kepler's third law of planetary motion as a mathematical or computational representation of orbital motion to depict that the square of a revolving body's period of revolution is proportional to the cube of its distance to a gravitational center ($T^2 \propto R^3$, where T is the orbital period and R is the semi-major axis of the orbit)

ESS1.B.6c Analyze Kepler's second law of planetary motion to predict the relationship between the distance between an orbiting body and its star, and the object's orbital velocity

ESS1.B.6d Analyze Kepler's third law of planetary motion to predict how either the orbital distance or orbital period changes given a change in the other variable

ESS1.B.6e Analyze Newton's law of gravitation and his third law of motion to predict how the acceleration of a planet towards the Sun varies with its distance from the Sun, and to argue qualitatively about how this relates to the observed orbits

Crosscutting Concept Assessment Target(s)

CCC3 Use algebraic thinking to examine scientific data and to predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth)

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides data from a simulation that displays the orbital period (T) and the semi-major axis orbit (R) for different planets in the solar system:

- Identifies the pattern between T and R for each planet and which law this represents (5.2.1, ESS1.B.6, and CCC3)

Task provides a table with data that was collected about various orbiting objects that includes their distance between foci and ellipse, and the ellipse's major axis length:

- Chooses from a list of choices what prediction from this data they can make regarding eccentricity and orbiting objects (5.2.1, ESS1.B.6, and CCC3)

Task provides a simulation of a comet orbiting the Sun where various conditions can be changed, including distance of the comet from the Sun and the velocity and mass of the comet:

- Evaluates how the comet's acceleration and/or force of attraction between the Sun and comet changes with respect to the change in the comet's distance and/or mass (5.2.1, ESS1.B.6, and CCC3)

Task provides data from a simulation that displays the orbital period (T) and the semi-major axis orbit (R) for different planets in the solar system and the period of a newly-discovered planet:

- Predicts the semi-major axis of the orbit (5.2.2, ESS1.B.6, and CCC3)

Task provides a simulation of a comet orbiting the Sun where various conditions can be changed, including distance of the comet from the Sun and the velocity and mass of the comet:

- Explains how the velocity changes with respect to the change in distance and which of Kepler's laws this simulation model assumes to follow (5.2.3, ESS1.B.6, and CCC3)

- Explains how the velocity of the comet changes with respect to the change in the comet's mass (5.2.3, ESS1.B.6, and CCC3)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- Kepler's three laws of planetary motion

- Newton's law of universal gravitation

Common Misconceptions

Note that the list in this section is not exhaustive.

- Orbits around the Sun are perfect circles.

- The acceleration of a planet is constant through its orbital period.

- The speed of an orbiting planet is dependent on its size and mass.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-ESS1-4 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-ESS1-4%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12*

Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12

HS-ESS3-1

Students who demonstrate understanding can:

> **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.**
>
> [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

Continue to the next page for the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

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 knowledge, principles, and theories. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**ESS3.A: Natural Resources** 4. Resource availability has guided the development of human society. **ESS3.B: Natural Hazards** 5. Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. --------------------------- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Modern civilization depends on major technological systems.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

6.1 Ability to construct explanations of phenomena

6.2 Ability to evaluate explanations of phenomena

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

6.1.1 Ability to construct a quantitative and/or qualitative explanations of observed relationships

6.1.2 Ability to apply scientific concepts, principles, theories, and big ideas to construct an explanation of a real-world phenomenon

6.1.3 Ability to use models and representations in scientific explanations

6.2.1 Ability to evaluate and revise a given explanation based on accepted scientific theory and/or data provided

6.2.2 Ability to use data to support or refute an explanatory account of a phenomenon

Disciplinary Core Idea Assessment Targets

ESS3.A.4a. Identify cause-and-effect relationships between environmental factors (e.g., access to fresh water, soil fertility, available natural resources) and features of human societies including population size and migration patterns

ESS3.A.4b. Describe the effect technology in modern civilization has on mitigating some of the effects of natural hazards, climate, and the availability of natural resources on human activity

ESS3.A.4c. Identify and describe evidence that supports the following claims:

- Changes in climate affect human activity (e.g., agriculture) and human populations and can drive mass migrations
- Features of human societies have been affected by the availability of natural resources
- Human populations depend on technological systems to acquire natural resources and modify physical settings

ESS3.A.4d. Use 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 to describe the availability of natural resources on features of human societies

ESS3.A.4e. Differentiate between causal and correlation relationships between environmental factors and human activity and describe potential sources of evidence that could support a proposed causal relationship

ESS3.A.4f. Describe differential trends in access to natural resources over time (e.g., that technology to access coal came before technology to access natural gas)

ESS3.B.5a. Identify cause-and-effect relationships between incidence of natural disasters and features of human societies including population size and migration patterns

ESS3.B.5b. Identify and describe evidence that supports the claim that changes to climate have a primary effect on human populations and a secondary effect (by altering the incidence of natural hazards)

ESS3.B.5c. Describe differential trends in incidence of natural hazards over time

Crosscutting Concept Assessment Target(s)

CCC2 Identify empirical evidence to differentiate between cause and correlation and make claims about specific causes and effects

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task presents a graph of geologic factors on one axis and human population size on another axis:

- Constructs an explanation about the relationships between the independent and dependent variables (6.1.1, ESS3.A.4, and CCC2)

Task provides data on geologic factors particularly related to climate and the impact of climate change and data of human populations:

- Uses the data as evidence to support an explanation of the impact of changes to climate on human migration (6.1.2, ESS3.A.4, and CCC2)

Task presents a model/diagram representing changes in human activity throughout history (including population, geographic distribution, resource use, or the development of resource-acquiring technologies) along with map of availability of a particular natural resource:

- Uses the model to construct an explanation of a human activity over time based on natural resource availability (6.1.3, ESS3.A.4, and CCC2)

Task provides a claim about the effect of a natural hazard or geologic event on human populations in conjunction with a data table:

- Identifies (with reasoning) whether the provided data is sufficient to support the claim (6.2.1, ESS3.B.5, and CCC2)

- Identifies aspects of the data that do or do not align to the claim (6.2.1, ESS3.B.5, and CCC2)

Task provides data on a given geologic factor that could affect human activity:

- Uses data as evidence to support or refute an explanation for how that factor contributed to known changes in human activity (6.2.2, ESS3.B.5, and CCC2)

Environmental Principles and Concepts

- EP1: The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

- EP2: The long-term functioning and health of terrestrial, freshwater, coastal, and marine ecosystems are influenced by their relationships with human societies.

- EP3: Natural systems proceed through cycles that humans depend upon, benefit from, and can alter.

- EP4: The exchange of matter between natural systems and human societies affects the long-term functioning of both.

- EP5: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- The distribution or availability of a natural resource throughout history

- The difficulty in acquiring natural resources throughout history

- The incidence of natural disasters

- Variation in climate

- Changes in sea level and coastline over time

- Unintended impacts of strategies designed to solve environmental problems
- Relationships between current population density and impact of natural disasters
- Relationships between current population density and availability of natural resources
- Relating technological changes to availability of resources or mitigating natural disasters

Common Misconceptions

Note that the list in this section is not exhaustive.

- Resources are universally distributed throughout the biosphere.
- Human populations have equal access to natural resources.
- Natural hazards and geologic events always negatively impact human populations.
- Human populations are not impacted by natural resource availability or natural disasters.
- The impact of resource availability on human populations has not changed with new technologies.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-ESS3-1 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-ESS3-1%20Evidence%20Statements%20June%202015%20asterisks.pdf

Environmental Principles and Concepts http://californiaeei.org/abouteei/epc/

California Education and the Environment Initiative http://californiaeei.org/

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12*
Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12
https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf
Appendix 2: Connections to Environmental Principles and Concepts
https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix2.pdf