

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

California Science Test—Item Content Specifications

# HS-ESS1-4 Earth’s Place in the Universe

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.*]

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 |
| --- | --- | --- |
| 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  1. 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., simulations) to identify patterns in natural and/or design worlds

5.2.2 Ability to use the results of computational models to identify the mathematical and/or computational representations that support a scientific explanation or a design solution

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

### Disciplinary Core Idea Assessment Targets

#### ESS1.B.6

* Represent, identify, and describe a mathematical and/or computational model of orbital motion including the trajectories of orbiting bodies (e.g., 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)
* 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 (T2R3, where T is the orbital period and R is the semi-major axis of the orbit)
* 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
* 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
* 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 include 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
* Factors that affect the motion of satellites orbiting Earth

## 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 velocity of a planet is constant through its orbital period.
* The speed of an orbiting planet is dependent on its mass.
* The orbital period (*T*) of a planet depends on its mass and its average distance from the Sun (*R*).

## 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 Evidence Statements June 2015 asterisks.pdf](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 <https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf>

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