**Planetary Motion**

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| **Lesson Objective:** | Students will use a computer model/simulation to test the effects of gravity and mass on the motion of planets in a solar system. | | |
| **Course (Topic):** | Planetary Orbits<br>Ellipses | **Lesson Duration (Period Minutes):** | 47 minutes |

| **NGSS** | **CCSS-M** |
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| **Performance Expectation(s)**<br>**HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.**<br>[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.]<br><br>**Disciplinary Core Idea(s)**<br>**ESS1.B: Earth and the Solar System**<br>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.<br><br>**Cross Cutting Concept(s)** | **Domain(s)**<br>Number and Quantity;<br>Functions; Linear, Quadratic, and Exponential Models;<br>Geometry<br><br>**Content Standard(s)**<br>N Q 2; Define appropriate quantities for the purpose of descriptive modeling.<br>F LE 1; Distinguish between situations that can be modeled with linear functions and with exponential functions.<br>F LE 6 ; Apply quadratic functions to physical problems, such as the motion of an object under the force of gravity.<br>G MG 1; Use geometric shapes, their measures, and their properties to describe objects<br>F IF 4; For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. |

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| **Scale, Proportion, and Quantity**<br>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).<br>- - - - - - - - - - - - - - - - - - - - - - -<br>Connections to Engineering, Technology, and Applications of Science, Interdependence of Science, Engineering, and Technology<br>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 | |
| **Science and Engineering Practice(s):** | **Mathematics Practice(s):** |
| **Using Mathematical and Computational Thinking**<br>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. | Construct viable arguments and critique the reasoning of others.<br>Students will run and observe multiple trials of the "orbiting bodies" model and from those repeated trials will be asked to draw conclusions based on their observations.<br>Model with mathematics.<br>The model itself is already constructed, but the students will be interacting with the model to observe results as the variable within the model are manipulated. |

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| **Materials:** | Websites that can be used to prepare teachers to be more conversant in ellipses and planetary motion:<br>https://btc.montana.edu/ceres/html/58Orbits/58orbits.html<br>http://www.windows2universe.org/our_solar_system/solar_system_1.html<br>http://www.coolmath.com/algebra/25-conic-sections/02-introduction-ellipses-01<br>http://www.intmath.com/plane-analytic-geometry/5-ellipse.php<br>http://www.askamathematician.com/2010/08/q-why-are-orbits-elliptical-why-is-the-sun-in-one-focus-and-whats-in-the-other/<br>https://www.youtube.com/watch?v=s77LJO6USEY (Kepler's Three Laws of Planetary Motion video. Show from 47 seconds to 2 minutes, 40 seconds on the video clip, skipping Kepler's Third Law details) |

| **Engage:** Connect to prior knowledge and experience. Focus students' thinking on learning outcomes. | **Estimated Time: 3 minutes** |
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**Take roll during "Exploring" segment while students are working with the model.**

**Description: Show short video clip on Kepler's Three Laws, but only the segment** from counter mark 47 seconds to 2 minutes, 40 seconds.
https://www.youtube.com/watch?v=s77LJO6USEY (Kepler's Three Laws of Planetary Motion video. Show from 47 seconds to 2 minutes, 40 seconds on the video clip)
Demonstrate how to construct an ellipse on chart paper with push pins, string and a marker pointing out the key features.

| Conceptual Focus | Teacher Does (including Questions to Ask) | Student Does (including Anticipated Responses) |
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| What is an ellipse?<br>Parts of an ellipse: | Show video clip. | Students view video. |

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| Major and minor axes<br>Foci/Focus<br><br>Mass<br>Gravity<br>Orbit | Pass out paper to draw the ellipse.<br><br>Constructing an ellipse demonstration.<br><br>"What happens to the lengths of the line segments. For example a. and b.?"<br>"Did the length of the string change?"<br><br>Note that the sum of the distance of a + b is always equal | Students sketch an ellipse on the student handout labeling the key parts. Identify foci.<br><br>one gets shorter as the other gets longer<br><br>no |

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| **Explore:** Students actively explore their environment or manipulate materials. Students identify and develop concepts, processes, and/or skills. | **Estimated Time: 3 - 5 minutes** |

**Description:**
Students will log into netlogo and open the "orbiting-bodies" model. While waiting for every student to download the NetLogo model, students have the opportunity to explore the model, including the various sliders making adjustments and observing the results. Students will then follow the instructions outlined on the Orbiting Objects Worksheet.

## Orbiting Bodies model download site:
## http://modelingcommons.org/browse/one_model/4005#model_tabs_browse_info

| Conceptual Focus | Teacher Does (including Questions to Ask) | Student Does (including Anticipated Responses) |
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| | Instruct students to type in a google search for "orbiting bodies netlogo model". Take the search result titled Orbiting Bodies, by Luke Elissiry (model ID 4005) -- NetLogo | Students perform the search and download the NetLogo Orbiting Bodies model on to their desktop. |

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| | Tell students to find the "download" link below the model picture, click on it, and open the model on their desktop, but not to play with it, yet, wait for further instructions. | | |
| **Explain:** Students explain the concepts they have been exploring. They verbalize their conceptual understanding or demonstrate new skills or behaviors. Teachers introduce formal terms, definitions, and explanations for concepts, processes, skills, and/or behaviors. | | | **Estimated Time: 5 minutes** |

**Description:**
Students show that they have acquired an understanding of the shape of planetary orbits, can identify an ellipse, and understand that gravity is the force that influences the shape and velocity of the elliptical orbits.

| Conceptual Focus | Teacher Does (including Questions to Ask) | Student Does (including Anticipated Responses) |
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| | Ask students to work in pairs to draw their conception of a solar system which includes a sun, planets, moons and and a comet or asteroid.<br><br>Ask students to write the words “fastest” and “slowest” on the orbital paths showing where each body orbiting the sun is moving its fastest or slowest. | Students sketch out the solar system as requested. |

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| **Evaluate:** Encourages learners to assess their understanding and abilities and lets teachers evaluate students' understanding of key concepts and skill development. | | **Estimated Time:** |
| **Description:**<br>(Same as Explain) Students show that they have acquired an understanding of the shape of planetary orbits, can identify an ellipse, and understand that gravity is the force that influences the shape and velocity of the elliptical orbits. | | |
| **Conceptual Focus** | **Teacher Does (including Questions to Ask)** | **Student Does (Anticipated Responses)** |
| | Use random questioning to ask students to show knowledge of orbital shape,<br><br>Collect students' papers after instructing them to put their names, date and period on their paper. | |
| **Extend:** Through new experiences, the learners develop deeper and broader understanding of concepts and refine their skills. | | **Estimated Time:** |
| **Description:** | | |
| **Conceptual Focus** | **Teacher Does (including Questions to Ask)** | **Student Does (including Anticipated Responses)** |
| | If time were to permit, ask students to draw another solar system which has two suns in it. This has the intent to both see if students have grasped the concepts above and to introduce | |

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| | the element of imagination. | |