Space Systems - Middle School

Draft Lesson Design by Debbie Brown Summer workgroup 2014

### Part A: Gather and Filter information from [NGSS](http://standards.nsta.org/AccessStandardsByTopic.aspx) and [PhET](http://phet.colorado.edu/) Interactive Simulations

**Step 1*:*****Select PEs and PhET Simulation(s) that work together.**

***1. a. Select PEs and Identify the associated Clarification Statements and Assessment Boundaries.***

Table 1a:

|  |  |  |
| --- | --- | --- |
| **Performance Expectation** | **Clarification Statement** | **Assessment Boundary** |
| Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. MS-ESS1-2 | Emphasis for the model is on **gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them.** Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state). | Assessment does not include Kepler’s Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth. |
| **PE**: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. MS-PS2-4 | **Clarification Statement:** Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system. | **Assessment Boundary:** Assessment does not include Newton’s Law of Gravitation or Kepler’s Laws. |

Note: Instruction will need to focus on the effects of gravity and how it acts as a force to keep the solar system together. In addition lessons should look at how gravity controls orbital motion.

***1. b. Evaluate PhET sims for alignment with PEs, Clarifications, Boundaries.***

Table 1b: PhET Simulation

|  |  |  |  |
| --- | --- | --- | --- |
| PhET Simulation | Main Topics | PhET Learning Goals | Summary and  Reflections |
| Gravity and Orbits | Gravitational Force  Astronomy  Circular Motion | Describe the relationship between the Sun, Earth, Moon and space station, including orbits and positions  Describe the size and distance between the Sun, Earth, Moon and space station  Explain how gravity controls the motion of our solar system  Identify the variables that affect the strength of gravity  Predict how motion would change if gravity was stronger or weaker | Focus of the sim is on the sun/earth/moon/satellite system  Students can manipulate the mass of the Earth and sun.  Students can observe the gravity vector and the speed vector as well as the path of each object |
| My Solar System | Motion  Acceleration  Velocity  Position  Gravity | Predict the necessary mass, velocity, and distance from the sun of a planet in order for this planet to make a circular orbit around a sun.  What happens when you increase or decrease the mass of the planet, but keep everything else constant? Does this agree with your prediction?  What happens to the orbit of the planet when you increase or decrease the magnitude of the velocity of the planet, but keep everything else constant?  What happens to the planet's orbit when the increase or decrease the initial distance between the planet and the sun? | Allows exploration of more than just a single planet system, ex. binary stars, asteroids.  Includes quantitative manipulation of mass |

**Step 2**: **Collect and Filter NGSS specifics for lesson.**

***2. a. Identify the three dimensions that are coded to the PEs.***

DCI (ESS):

* Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
* The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
* The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

End of Grade Band: students should know structure: Earth → solar system → galaxy → universe. Structure of our solar system and how gravity holds it all together. Finally how scientists believe gravity caused the solar system to form.

Note: The third DCI, “the solar system appears….” actually falls under HS on the NSTA NGSS grade band indicators despite being under MS on the DCI page.

Note: grade band: The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons. This instruction will **NOT** cover eclipses, lunar phases and seasons and will focus only on the effects of gravity.

DCI (PS):

* Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

End of Grade Band: students should connect their understanding of gravity to the structure of the solar system and how it formed in the ESS standard. Relating the effect of mass to the formation.

Science and Engineering Practices:

#### **Developing and Using Models**

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

* Develop and use a model to describe phenomena. (MS-ESS1-1), (MS-ESS1-2)
* Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
* Evaluate limitations of a model for a proposed object or tool.
* Use and/or develop a model of simple systems with uncertain and less predictable factors.
* Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
* Develop and/or use a model to predict and/or describe phenomena.
* Develop a model to describe unobservable mechanisms.
* Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Note: The practices listed above are all the practices related to models. May reduce the focus with a later step in planning, all listed for now.

#### **Engaging in Argument from Evidence**

Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

* Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Cross Cutting Concepts:

Systems and Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

* Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-ESS1-1), (MS-ESS1-2)
* Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

***2. b. Use DCI grade band progressions and/or Appendix E for previous and future grades.***

**Table 2b: Grade Level Bands DCIs**

|  |  |  |  |
| --- | --- | --- | --- |
| **Former DCIs** | **Target DCI** | **Future DCI** | **Content Elaboration** |
| The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. | **Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.**  **~~Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.~~** | The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.  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. | **Know: sun, star, sizes and distances of stars varies. Brightness of stars in relation to distance from Earth. Order of the solar system**  **Learn: Milky Way galaxy, many galaxies. Idea on the structure universe**  **Optional Extension: galaxy shapes and how these might form, discoveries of galaxies and developing technology** |
| The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. | **The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.**  **~~This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.~~** | 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.  Cyclical changes in the shape of 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.  The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. | **Know: cause of day, night seasons and changes in positions of objects in the night skies, eclipses. Rotation, orbit, revolution creating patterns. Tilt and impact of sunlight intensity different areas Earth**  **Learn: The gravitational pull of the sun holds our solar system together. Impact on the movement of different objects by gravity**  **Optional Extension: Structure other solar systems discovered as compared to our own. Impact gravity on path of a comet.** |
| Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. | **The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.** | **See above HS DCI** | **Know: What are the patterns in the motion of the sun, moon and stars that we are able to observe (change in constellations, phases moon, sun east to west)**  **Learn: How gravity pulled the solar system together. Attraction of objects based on mass. What a disk is.**  **Optional Extension: What evidence do we have that other galaxies are forming due to gravity? Impact of a binary system on the shape of a solar system? Black holes, evidence of?** |
| Objects in contact exert forces on each other.  Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.  The gravitational force of Earth acting on an object near Earth’s surface pulls that object toward the planet’s center. | Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. | Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.  Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.  Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. | **Know: What a force is and that objects exert forces on each other. You do not have to be in contact to exert a force, ex electricity and magnetism. Size of the force depends on properties like: mass, distance between, orientation. The Earth’s Gravity is a force that pulls objects toward the center of our planet.**  **Learn: Gravity always pulls objects together. No matter the mass, there is always a gravitational force of attraction. The larger the mass of an object the easier it is to observe the effect of gravity.**  **Optional Extension: What evidence do we have that small objects exert a gravitational pull? (NASA video of dice)** |

***2.c. Select additional Science and Engineering Practices that support your chosen DCIs and CCs.***

*Asking Questions and Defining Problems*

* *that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.*
* *to identify and/or clarify evidence and/or the premise(s) of an argument.*
* *to determine relationships between independent and dependent variables and relationships in models..*

*Constructing Explanations and Designing Solutions*

* *Construct an explanation using models or representations.*

*Obtaining, Evaluating, and Communicating Information*

* Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evid
* *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) 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.*

***2.d. Select related Common Core Mathematics Standards (CCSS-M) and Common Core Literacy Standards (CCSS-L) related to the PE’s selected.***

#### **ELA/Literacy**

* **RST.6-8.1** - Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS1-3)
* **RST.6-8.7** - Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ESS1-3)
* **SL.8.5** - Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-ESS1-1)

**Mathematics**

* **6.RP.A.1** - Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-ESS1-1), (MS-ESS1-2), (MS-ESS1-3)
* **7.RP.A.2** - Recognize and represent proportional relationships between quantities. (MS-ESS1-1), (MS-ESS1-2), (MS-ESS1-3)
* **MP.2** - Reason abstractly and quantitatively. (MS-ESS1-3)
* **MP.4** - Model with mathematics. (MS-ESS1-1), (MS-ESS1-2)

### Part B: Plan your lesson using Part A and PhET’s teacher tools.

**Step 3**: **Refine lesson focus**

**3. *a. Break the DCI into lesson segments***

Table 3: Determining Knowledge for instruction

|  |  |  |
| --- | --- | --- |
| Prior Knowledge | Grade Level Band | Not Addressed (future) |
| Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.  Earth and its solar system ~~are part of the Milky Way galaxy, which is one of many galaxies in the universe.~~ | ~~Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.~~  Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. | ~~Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.~~  ~~Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.~~ |
| The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids ~~that are held in orbit around the sun by its gravitational pull on them.~~  This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. | The solar system ~~consists of the sun and a collection of objects, including planets, their moons, and asteroids~~ that are held in orbit around the sun by its gravitational pull on them.  ~~This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.~~ | ~~The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.~~  ~~This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.~~ |
| ~~The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.~~ | The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. | ~~The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.~~ |
| ~~Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.~~  ~~Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.~~  ~~Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).~~ | ~~Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.~~  Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.  ~~Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).~~ | Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.  Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. **Addressed again in a later instructional unit on force.**  Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). |

***3. b. Blend the Practices, DCI Target Segments, and CCs into lesson-specific PEs and sequence the lesson progression.***

**Table 3b: Develop Lesson Level PEs**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Lesson**  **Part** | **Science and Engineering Practice** | **Disciplinary Core Idea** | **Crosscutting Concept** | **Lesson Level Expectations** | **Instruction Ideas** |
| Part 1 | *Asking Questions and Defining Problems*  *that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or* ***seek additional information.*** | Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. | Systems and System Models | Ask questions relating to the appearance of solar system, galaxies and universe.  Outline/diagram the structure of the universe and define problems in our understanding of the universe. | Question: What is our place in the universe?  Pre Assess: Illustrate what the universe looks like, then discuss our illustrations as a class or small group to generate questions for further understanding as well as address misconceptions.  Explore Gravity and Orbits Simulation  Class discussion after individual explorations using the gravity and orbits sim - what questions do we have about why the solar system looks like it does? |
| Part 2 | Developing and Using Models: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. | The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. | Systems and Models | Revise models of the solar system and its components to show the effect of changing gravity on motion of different objects. | Write hypotheses from the class questions that can be tested using the model.  Lesson using Gravity and Orbits sim. Extension the My Solar System simulation for more complex ideas |
| Part 3 | Engaging in Argument from Evidence:  Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. | Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. | Cause and Effect | Gather evidence to construct a written argument explaining why mass is important to understanding gravity and how changing mass affects gravitational force. | Gravity and Orbits sim - How is gravity affect planets and other objects in space?  mass and distance matter to things pulling on each other |
| Part 4 | Obtaining, Evaluating, and Communicating Information: Integrate qualitative and/or quantitative scientific and /or technical information in written text with that contained in media and visual displays to clarify claims and finding. | The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. | Systems and Models | Create and explain a model to combine information from readings, video, and simulations to support the argument that gravity is the driving force for the formation of our solar system. | Why is gravity a force that rules the universe? |

**Step 4**:**Determine evidence for formative and summative assessment**

**Table 4: Assessment Evidence**

|  |  |  |
| --- | --- | --- |
| **Lesson Segment** | **Lesson Level PE / PhET Learning Objective**  **(PhET Objectives in bold)** | **Evidence** |
| Part 1. | **Gravity and Orbits: Describe the relationship between the Sun, Earth, Moon and space station, including orbits and positions.**  Ask questions relating to the appearance of solar system, galaxies and universe.  Outline/diagram the structure of the universe to define problems in our understanding of the universe. | Pre-Assess: Illustration of universe picture/diagram.  2 or 3 scientific questions  Evaluation of questions with clarification comments  Final diagram/model of structure universe |
| Part 2. | **Gravity and Orbits: Explain how gravity controls the motion of our solar system**  Revise models of the solar system and its components to show the effect of changing gravity on motion of different objects. | Identification of variables related to gravity and motion  Formulation of hypothesis  (If…then…because…)  Clearly recorded observations  Conclusion written in form of “claim, evidence, reasoning, conclusion” (CERC) |
| Part 3. | **My Solar System: What happens when you increase or decrease the mass of the planet but keep everything else constant?**  Gather evidence to construct a written argument explaining why mass is important to understanding gravity and how changing mass affects gravitational force. | Clearly recorded data/evidence  Written argument in form of “claim, evidence, reasoning, conclusion” (CERC) |
| Part 4. | Create and explain a model to combine information from readings, video, and simulations to support the argument that gravity is the driving force for the formation of our solar system. | Presentation of model |

**Step 5**: **Develop a Big Idea and Lesson Plans**

**Part 1. Guiding Question: How is the universe structured? OR What is our place in the universe?**

* Pre-assess: Create an illustration of how the universe is structured.
* Class discussion of different student representations.
* Write 2 or 3 questions that could be asked to clarify our picture of the universe based on discussion of illustrations. What do we need to learn in order to be able to accurately visualize the universe?
* Explore *Gravity and Orbits PhET Simulation* (10 minutes)
* Following initial *Gravity and Orbits Simulation* exploration, write 2 or 3 scientific questions that can help us clarify our initial picture of the universe and the role of gravity.
* Trade and provide feedback: evaluate another lab groups question list, provide feedback on list of questions for clarity and connection to the simulation.

**Part 2. Guiding Question: What role does gravity play in our solar system?**

* Select one question from groups list and formulate a hypothesis to test using the simulation. Share and evaluate group hypotheses.
* Complete conclusion following the CERC format. Share results to examine impacts of different variable changes.

**Part 3. Guiding Question: How does gravity “work’?**

* Exploration of *My Solar System Simulation* (10 minutes)
* Class discussion of how this simulation is different from *Gravity and Orbits Simulation.*
* Complete *My Solar System Simulation* activity
* Teacher may provide class readings and video options related to gravity for students

**Part 4. Guiding Question: How does gravity rule the universe?**

* Summative: Students will compile information from class readings, videos and simulations to demonstrate their understanding of the role gravity plays in the formation and motion of the solar system.

**Step 6**: **Re-examine lesson**