Gravity and Orbits

Lesson Objective:	Students will be able to: ● Draw motion of planets, Moons and satellites. ● Draw diagrams to show how gravity is the force that controls the motion of our solar system. ● Identify the variables that affect the strength of the gravity. ● Predict how motion would change if gravity was stronger or weaker. ● Solve problems using Kepler's Third Law		
Course (Topic):	Earth Science (Motion of Orbiting Objects)	**Lesson Duration (Period Minutes):**	2 periods (55 minutes each)

NGSS	**CCSS-M**
Performance Expectation(s) HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. **Disciplinary Core Idea(s)** ESS1.B Earth and the Solar System 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.	**Domain(s)** Reasoning with Equations and Inequalities Quantities **Content Standard(s)** A-REI.B Solve equations and inequalities in one variable. A-REI.4b Solve quadratic equations by inspection (e.g., for $x^2 = 49$), taking square roots, ~~completing the square, the quadratic formula and factoring~~, as appropriate to the initial form of the equation. ~~Recognize~~

Cross Cutting Concept(s) 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).	~~when the quadratic formula gives complex solutions and write them as a±bi for real numbers a and b.~~ N-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.★
Science and Engineering Practice(s):	**Mathematics Practice(s):**
SEP 5 Using mathematics and computational thinking.	MP 4 Model with mathematics.
Materials:	Powerpoint, Gravity and Orbit Phet Simulation https://phet.colorado.edu/en/simulation/gravity-and-orbits Gravity and Orbits handout adapted from (parts 1,2 ,3) https://teacher.ocps.net/maria.bermudez2/static/GravityAndOrbits-StudentActivity1.pdf and (part 4) http://www.uni.edu/morgans/astro/course/Notes/section1/math3.html Calculators, individual whiteboards and markers for each student

Engage: Connect to prior knowledge and experience. Focus students' thinking on learning outcomes.	**Estimated Time:** 15 minutes
Description: Review vocabulary and concepts from previous lesson and connect to today's lesson by having students watch a video of the solar system and generate questions about the movement of the planets.	

Conceptual Focus	Teacher Does (including Questions to Ask)	Student Does (including Anticipated Responses)

Earth's motion	Distribute individual whiteboards and markers as students enter. Begin the lesson by reviewing vocabulary. Call on volunteers to answer the question or add on to what other students say.	
	What are the two Earth's motions?	The Earth revolves and rotates.
	What does it mean to rotate?	When the Earth rotates it spins on its axis.
	What evidence do we have that it rotates?	Day changes into night.
	What does it mean to revolve?	When the Earth revolves, it orbits the Sun.
	What evidence do we have that it revolves?	The changes in the seasons and the position of the constellations in the night sky. The constellations are higher or lower in the sky.
Gravity	***What is gravity?***	Gravity is a force that pulls everything toward the center of the Earth.
	Tell students to watch the video of our solar system and to write down on their whiteboards anything they notice and any questions that come to mind.	Students will get whiteboards, pens, and napkins.
	Show the video of the solar system then write down students responses (observations and questions) on the board by calling on non-volunteers and volunteers.	
	What do you notice?	The planets' orbits are circular and elliptical. Some planets are bigger than others. The inner planets orbit faster.

	What do you wonder about what you see? Tell students that in today's lesson we hope to answer some of these questions. Go over the lesson objectives on the PowerPoint.	The outer planets orbit slower around the sun. All planets move counterclockwise. Planets rotate at different speeds. Each planet has its own path. Eight planets orbit one sun. The Earth is the third planet from the Sun. Some of the planets get shaded while revolving (solar eclipse). Why do the planets orbit at different speeds? What determines whether it revolves faster or slower? Why do planets revolve counterclockwise? Why don't the planets orbit in the same path? What causes the planets to orbit? Does the Sun rotate? Why are the planets revolving? Why can't they stay in place? Why do the planets revolve and the Sun does not? I wonder why the planets do not crash into each other? Why are some planet's orbits smaller than others? Why are some planets closer to the sun?

Explore 1: Students actively explore their environment or manipulate materials. Students identify and develop concepts, processes, and/or skills.	**Estimated Time:** 10 min
Description: Students complete Part 1 of the handout.	

Conceptual Focus	Teacher Does (including Questions to Ask)	Student Does (including Anticipated Responses)
Motion of the Sun, Earth, and Moon	Distribute the handout and tell students to go to the Gravity and Orbits pHet simulation using the URL on the handout or by searching for it. Explain the controls on the panel while students select the choices with you. Ask questions to check for understanding as you explain each, such as "***What happens when you click…"*** 1) Four choices on what to work with: Sun, Earth, moon, and satellite. Today you will only work with the first and third systems. 2) Switch gravity on or off. 3) Four things to show. a) Gravity force is a blue arrow. The length of the arrow shows the magnitude of the force. ***Where do the arrows originate? Where do the start from?*** b) Velocity is a red arrow. Do not use today. c) Path. Will show the path of the orbit.	Students "play" with the simulation while the teacher shows them things they can change. They ask and answer questions when prompted. The start at the center of the object (Sun, Earth, moon) and point outward.

	When you are asked to draw the path, make sure you draw a whole revolution. d) Grid. Places a grid on the screen. It might help you measure distance. 4) Mass sliders allow you to increase or decrease the mass of the Sun, Earth, moon, or satellite. Explain that the slider in the upper left corner lets you zoom in or out. At the bottom of the screen there is a play button which will start the motion of the Sun, Earth, moon, or satellite. The slider lets you increase or decrease their speed. Tell students to refer to the handout. If short on time, skip number 1 since that was just done together. Tell them to click Reset All, complete Part 1 and be ready to share out with the class. Circulate while students work and provide corrective feedback as needed.	Students work with a partner to complete #2. Faster students may complete both drawings on their own.
Explain 1: 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 min
Description: Students explain what was the same and different about the Earth's movement around the Sun and the Moon's movement around the Earth.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (including Anticipated Responses)**
	When most students are about done with Part 1, regroup the class and discuss their findings.	

	Who would like to share how the motions were similar? ***Who would like to share how the motions were different?***	Both had circular orbits and moved counterclockwise. It took a different amount of time to complete an orbit. The moon takes about 30 days to orbit the Earth. The Earth takes about 370 days to orbit the Sun.

Explore 2: Students actively explore their environment or manipulate materials. Students identify and develop concepts, processes, and/or skills.	**Estimated Time:** 10 min
Description: Students complete Part 2, #3 of the handout.	

Conceptual Focus	Teacher Does (including Questions to Ask)	Student Does (including Anticipated Responses)
Gravity in the Sun and Earth system	Tell them to click Reset All, click the Sun and Earth system, complete #3 in Part 2 and be ready to share out with the class. Circulate while students work and provide corrective feedback as needed.	Students compare the path of the Earth when there is gravity to when there is no gravity.

Explain 2: 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 min
Description: Students explain why gravity is important.	

Conceptual Focus	Teacher Does (including Questions to Ask)	Student Does (including Anticipated Responses)

	When most students are about done with #3, regroup the class and discuss their findings. ***Why do you think gravity is important?***	If there is no gravity, we (Earth) would float off into outer space. Gravity keeps us orbiting/revolving around the Sun. We might crash into other planets.
Explore 3: Students actively explore their environment or manipulate materials. Students identify and develop concepts, processes, and/or skills.		**Estimated Time:** 10 min
Description: Students complete Part 2, #4 of the handout.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (including Anticipated Responses)**
Gravitational Force	Tell students to click Reset All. Point out that they will be drawing the gravitational force for two different systems, the Sun/Earth system and the Earth/Moon system. Suggest that they might want to turn on the grid so they get accurate lengths of the gravitational force. Tell them to complete #4 in Part 2 and be ready to share out with the class. Circulate while students work and provide corrective feedback as needed.	Students draw the gravitational force between the Earth and Sun and Earth and moon and consider why one revolves around the other.
Explain 3: 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 min
Description: Students describe the gravitational force between two bodies.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (including Anticipated Responses)**

	When most students are about done with #4, regroup the class and discuss their findings. ***What did you notice about the gravitational force between the two bodies?*** ***What did you notice about the direction of the forces?*** Explain that the gravitational forces were equal but opposite.	The gravitational forces were equal because the arrows were the same length. The gravitational forces were pointing toward each other.
Explore 4: Students actively explore their environment or manipulate materials. Students identify and develop concepts, processes, and/or skills.		**Estimated Time:** 10 min
Description: Students complete Part 2, #5 and 6 of the handout.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (including Anticipated Responses)**
Gravitational Force	Tell students to click Reset All and click on the Sun/Earth system and Gravity Force. Tell them to complete #5 and 6 in Part 2 and be ready to share out with the class. Circulate while students work and provide corrective feedback as needed.	Students explore different actions with the Sun and Earth to either increase or decrease the length of the blue arrows.
Explain 4: 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 min
Description: Students explain how to increase or decrease the gravitational force between two bodies.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (including Anticipated Responses)**

	When most students are about done with #5 and 6, regroup the class and discuss their findings. Record their findings on the board.	
	What actions can increase the gravitational force?	The gravitational force can increase when the mass increases or when the distance between the two bodies decreases (move them closer together).
	What actions can decrease the gravitational force?	The gravitational force can decrease when the mass decreases or when the distance between the two bodies increases (move them farther apart).
	Write the formula for the Force of Gravity on the board. $F_g = \frac{Gm_1m_2}{r^2}$.	
	Explain that in physics, this formula represents the gravitational force between two objects (Universal Gravitation Equation), where G is a gravitational constant, m_1 and m_2 represent the masses of each object, and r represents the distance between the two objects, as measured from the center of each object.	
	What happens if we increase the value of m_1?	Gravitational force increases (because the numerator increases).
	What happens if we increase the value of m_2?	It increases for the same reason.
	What happens if we increase the value of r?	Gravitational force decreases (because the denominator increases).

Explore 5: Students actively explore their environment or manipulate materials. Students identify and develop concepts, processes, and/or skills.	**Estimated Time:** 10 min
Description: Students complete Part 3 of the handout.	

Conceptual Focus	Teacher Does (including Questions to Ask)	Student Does (including Anticipated Responses)
Gravity and Motion	Tell students to click Reset All. Tell them explore factors affecting orbits by investigating three different scenarios. Tell them to complete #7 in Part 2 and be ready to share out with the class. Circulate while students work and provide corrective feedback as needed.	Students "play' with the different systems using what they know about mass, distance, and gravitational forces.

Explain 5: 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 min
Description: Students describe the gravitational force between two bodies.	

Conceptual Focus	Teacher Does (including Questions to Ask)	Student Does (including Anticipated Responses)
	When most students are about done with #7, regroup the class and discuss their findings. ***How did you make the moon go around the Earth in a bigger circle?*** ***How did you increase the time it takes the Earth to go around the Sun?***	If you increase the distance between the bodies, the orbit increases and becomes more oblong in shape. It also takes longer to complete one revolution.

	How did you decrease the time it takes the Earth to go around the Sun?	If you decrease the distance between the bodies and increase the mass of the Earth, it will take less time for the Earth to orbit the sun and the path becomes less circular.
Evaluate: Encourages learners to assess their understanding and abilities and lets teachers evaluate students' understanding of key concepts and skill development.		**Estimated Time:**
Description: Close the lesson by referring back to the questions students generated at the beginning of the lesson. Select appropriate questions they should be able to answer as a result of the lesson and have them respond to each question in writing.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (Anticipated Responses)**
	Refer back to the list of questions generated by students. Read each one and ask if they are able to answer it based on what they learned in the lesson. If students are unsure, have them discuss with a partner. After going through the questions, either give them a handout with the questions you pre-selected for them to answer or mark the questions on the board you want them to answer and have them respond on their own paper.	Students reflect on the questions generated at the beginning of the lesson and write a response to the ones they should be able to answer.
Extend: Through new experiences, the learners develop deeper and broader understanding of concepts and refine their skills.		**Estimated Time:** 15 min
Description: Students complete Part 4 of the handout. Additional questions may be found by referring to the original document cited.		
Conceptual Focus	**Teacher Does (including Questions to Ask)**	**Student Does (including Anticipated Responses)**
	Tell students that Kepler's Third Law shows the relationship between the period (time) of an object's orbit and the average distance that it is from the thing is orbits.	Students complete the problems on the handout.

	Clarify the formula and units as needed (e.g. AU ≈ 158 million kilometers). Have students complete Part 4. Tell them to consider how precise (where to round to) their answers need to be based on the context of the problem. Also remind them to label their answers with appropriate units.	