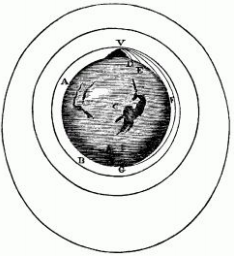
**Gravity in the Galaxies - Parent Guide (Answer Key)**



**Day 1: Engage – Phenomenon**

In this task, you will explore what factors affect motion within our solar system.

1. Isaac Newton was very curious about what affects the motion of celestial bodies in our solar system. He presented a thought experiment called “Newton’s Cannonball,” in which he imagines a cannon on top of a very high mountain. Newton said that logically, the cannonball should follow a straight line away from Earth, in the direction it was fired, instead of falling.
2. Do you agree? Why or why not?

**Answers may vary.**

The motion of the cannon ball depends on the force used to launch it. If the used is greate enough to overcome Earth’s gravity then the ball will travel away from Earth until another object enters the path of the cannon ball. This other object may stop, slow, or change the path of the cannon ball. If the force used to fire the cannon ball is too weak, the cannon ball with shoot out of the cannon and fall back to Earth. If the force is just right, the cannon ball will travel in a continuous orbit around the Earth.

1. Developing and Using Models: Use the following simulation to engage with Newton’s cannonball thought experiment: <http://physics.weber.edu/schroeder/software/NewtonsCannon.html>
2. If you set it to 1500 m/s, what happens? Explain why you think it moves this way.

The ball launches out and eventually comes crashing back to Earth. The ball doesn’t have enough forces to pull away from Earth’s gravity.

1. The moon orbits at 7,300 m/s. If you set the cannonball to this speed, what happens? Why is this different from the first setting? The ball launches out and begins to orbit the Earth. The first setting the ball came back down to Earth.
2. Now set it to 8000 m/s. What happens? How would you describe the relationship of an object’s speed and the force of gravity when it comes to orbits? The cannon ball orbits the Earth, but in a larger and more elliptical path. ; The more speed an object, the more it will overcome gravity and cause the orbit to be larger, or farther away.
3. Systems and System Models: You learned about gravity earlier this year. Gravity is the force that attracts objects towards physical bodies that have mass. Based on this definition, what object in our solar system do you think has the largest gravitational pull? The Sun would have the largest gravitational pull because it has the most mass.
4. How do you think this can explain the ways objects move in the solar system?

Objects with less mass orbit around objects with more mass. For example, the Earth orbits the Sun because the Sun has more mass and gravity. The gravity of the Sun attracts the Earth (and other bodies in the solar system) and pulls them into an orbital path. The other force that helps to keep bodies in orbit is inertia. Gravity attracts celestial bodies towards each other, but inertia keeps the bodies in motion and helps to keep the bodies from colliding. (Student answers may not include inertia because the focus of this lesson is gravity)

**Day 2-3: Explore**

Newton’s Cannonball is just one thought experiment which Isaac Newton used to hypothesize about the role of gravity in the motion of planets. Since then, scientists have used new technology to collect much more data that examines how objects move in the solar system. From this data, scientists have created models that not only describe current motions in the solar system but also how they started.

Systems and System Models: Explore the models below to form your own idea of how different parts of the solar system interact & why. Answer the questions that follow to help you describe each model.

**Model 1:** Simulating the Formation of Our Solar System

How did our solar system come to look the way it does? Before we simulate how the solar system was formed, we need to get some background. About 4.5 billion years ago, a dense cloud of gas and dust collapsed, forming a swirling disk of material. At the center, gravity pulled more and more material in until the pressure was so great that chemical reactions began releasing tons of energy. The sun was born from this interaction, using up 99% of the matter. However, matter farther out was also clumping together, forming larger objects. Some became planets, dwarf planets, and large moons. Others never quite came together and are part of the asteroid belt.

1. Visit the online simulation: <http://www.nowykurier.com/toys/gravity/gravity.html>

2. In the bottom left corner, click on “Huge” & then click “Generate proto disk (slow start)” to begin the sim.

3. Observe for approximately 30 seconds.

**Discussion Questions**

1. What appears to be happening?

The particles in the middle begin to collide and form a larger red body. The particles begin to move and orbit around he red body. The small particles collide together and form medium orange bodies and small yellow bodies. The Red body in the middle doesn’t seem to move, but all the other particles or bodies move around the red body. The particles eventually stop spreading outward and develop more consistent orbital paths around the red body.

2. What does this model imply as the main reason all of the planets orbit the sun?

The sun is the largest and most massive body in our solar system. All other bodies (planets, asteroids, etc) are less massive and are held within the gravity of the Sun.

**Model 2:** Simulating an Orbit with Our Bodies

This model simulates the motion of one planet in the solar system, so you can get a better feel for orbits.

1. Have one family member stand in the center holding one end of the rope or string. This person will represent the “Sun” and will not move from that spot, but will rotate or spin for the sake of this activity (Note: the sun does not actually rotate in reality).

2. You should hold the other end of the rope behind your back and start walking away from the motionless “Sun.” You will represent the “planet.”

3. You should revolve (walk) in a circle with the rope pulled taut until a full orbit is made around the “Sun”. Repeat the process several times.

**Discussion Questions**

1. When the rope becomes taut, what happens?

The planet (person) cannot move farther away. This represents gravity. The gravity of the Sun prevents the planets from move outward or away from the Sun.

2. How does the pull of the rope affect the direction and motion (orbit) of the planet?

The pull of the rope can influence if the planet orbits clockwise or counterclockwise. The faster the rope moves the faster the planet orbits. The more rope, the farther away the planet orbits, which increases the amount of time it takes for the planet to orbit. Shorter rope will cause the planet to orbit the Sun in less time.

3.What do you think the force of the rope pulling on the “planet” represents?

This force represents the force of gravity. In this model the rope holds the two people together. Similar to how the force of gravity hold the planets to the Sun.

**Model 3:** Simulating a Factor That Affects Solar System Movement

Now that we have a better idea of how our solar system formed and an example of a planet’s orbit, it’s time to think about what factors affect these motions.

1. Visit the online pHET simulation entitled “Gravity and Orbits”: <https://phet.colorado.edu/en/simulation/gravity-and-orbits>

2. Launch the simulation and select “Model.”

3. Click the selection showing the Sun, Earth, & Moon. Then click the boxes to show Gravity Force and Path.

4. Experiment with different masses of the Sun and Earth.

**Discussion Questions:**

1. How does the mass of the Sun impact the orbit of the Earth? Use an example from the simulation.

The size of the Sun impacts the size of Earth’s orbit. For example, if the Sun is increased to 1.5, the Earth moves closer and continues a shorter orbit (approximately 190 days). The force of gravity increased, because the mass of the Sun increased. If the mass of the sun is decreased to .5, the Earth moves farther away and continues a much longer orbit.

2. How does the mass of the Earth affect the Moon? Use an example from the simulation.

The size of the Earth impacts the size of moon’s orbit. For example, if the Earth is increased to 1.5, the moon moves closer and continues a shorter orbit (approximately 15 days). The force of gravity increased, because the mass of the Earth increased. If the mass of the Earth is decreased to .5, the moon moves farther away and continues a much longer orbit.

3.We learned that mass affects gravitational force. But how does this work in the solar system? Use examples from the simulation to explain how mass affects gravitational force in the solar system.

First, objects with more mass have more gravitational force. For example, the Sun has the most mass and all other celestial bodies orbit the Sun. In the simulation the moon orbits the Earth because the Earth is more massive. Second, each planet has its own gravity because of the mass of the planet. The gravity on Earth is more than the gravity on the moon, because the moon is smaller. When standing on the moon an astronaut would be able to jump higher because of the reduced amount of gravity. Third, a planet’s orbit is affected by gravity. A larger Sun with more gravity will cause the planet to travel around the Sun with more speed. A smaller Sun with less gravity will cause the planet to travel around the sun with less speed. For example, by increasing the mass of the Sun, the Earth orbited at a faster rate.

**Day 4: Explain Using Models**

The [video](https://www.youtube.com/watch?v=9R5P9Y9gRYY) shows a simulated solar system, created from authentic data on the solar system. Use the models you explored above to individually explain this simulation, describing the role of gravity in the motions within the solar system. In your explanation, you may want to:

❏ Describe the orbits of the planets

❏ Including what they are all orbiting around

❏ And why they are all in orbit

❏ Describe what factors and forces affect these orbits

Use evidence from the three models of the Explore to backup your explanation!

Answers may vary.

The simulation shows the planets circling the much larger sun because its mass is greater than that of the planets. In model 1, the smaller orange and yellow bodies circled the red body due to its larger size, just like in the simulation where the smaller planets are circling the much larger sun. In model 2, ropes were used to demonstrate the sun’s gravitational force on the planets. Like in the model, our solar system simulation showed planets orbiting the sun at various distances. In both model 2 and the simulation, objects closer to the sun (shorter ropes) move at a faster rate than objects farther away from the sun (longer ropes) due to the sun’s gravitational pull being stronger on objects that are closer to it.

**Day 5: Evaluate and Reflect**

1. On Day 1 of this lesson, you used a thought experiment (Newton’s Cannon Ball) to think about why planets might move the way they do in our solar system. Look back at your response for Day 1. After completing this lesson, how would you add to or revise your responses? Use information from the models to improve your explanation of Newton’s thought experiment.

Answers may vary.

I might include discussion based on how large the ball is in comparison to Earth to discuss how gravity would affect the cannon. In Model 3, it was shown that if we decrease the size of Earth, the moon would be larger would move further away from the Earth and experience a longer orbit. If we increase or decrease the size of the cannon, its orbit would be affected similarly to that of the moon. After completing the models, I might also include information about how the height of the mountain might affect the orbit of the cannon. The distance the cannon is from Earth would affect the speed of the ball, like the affects the rope lengths had on the objects in Model 2. Shorter distances cause the object to move faster, and longer distances cause the objects to move slower.

2. In this lesson, we focused on the crosscutting concept of Systems and System Models (models can be used to represent systems and their interactions). Where did you see examples of Systems and System Models in this lesson?

Answers may vary.

We used multiple models in this lesson to represent how gravity affects the planets and the paths they take around the sun. Due to the solar system being so massive, we had to find objects that we could work with to mimic the interactions taking place in our universe. Models 1 and 3 used simulations to aid in understanding of how objects in space interact with each other based on size. In Model 2, we used people and ropes to represent how distance affects the gravitational force and speed of planets orbiting around the sun. Each of these models and the video of our solar system help us visualize and study how the sun, the planets, and other objects interact with each other in our universe.

3.Now that you have used and developed models to describe the movement of celestial bodies in our solar system, what questions do you still have?

Answers may vary.

**Optional Challenge:**

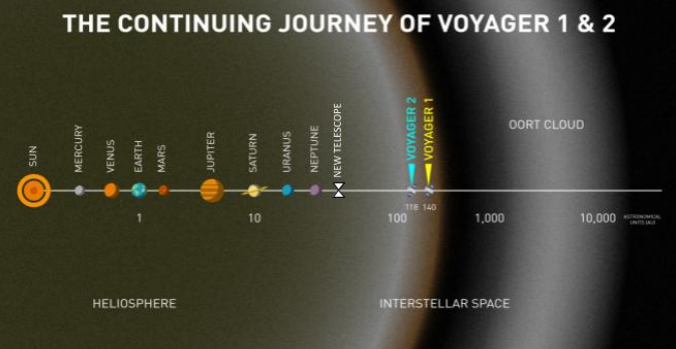
You will now begin to brainstorm the best route a new telescope should take through space. After working through the lesson above you saw several different models of our solar system. During this you would have developed a better understanding for how objects within the solar system move in relation to each other due to gravity. Based on what you’ve learned about mass, gravity, and motion, you develop a potential route for a new telescope on a sketch of the solar system.

**Background on the New Telescope**

NASA’s new telescope will carry different science instruments to take pictures of and collect information about the physical characteristics and compositions of astronomical objects. One of the things it will look for is water and other clues about the potential habitability (ability to live) in another planetary system.

Instead of orbiting the Earth, as the current space telescope does, this telescope will orbit the sun! This gives it a spectacular view of objects in the solar system. With this view, it will be able to observe the water cycle on Mars, look at weather patterns on Saturn’s moon Titan, hunt for new rings around the giant planets, and track different comets.

As you consider your route, consider that the telescope needs to get to the outside edge of the solar system, past all of the planets. Take a look at the image below: This shows the final desired location of the new telescope, but keep in mind that this drawing is not to scale, and in reality, planets are not organized in a straight line. Once in place, the telescope will orbit the sun as quickly as Earth does. This keeps the telescope in line with the Earth, offering it a unique vantage point, and allowing the Earth to protect the telescope from most of the light and heat from the sun.



1. Show and describe a potential route for the telescope within the model shown above.

Answers may vary, but should contain the following elements:

* + Telescope starting point-Earth and ending point- just beyond Neptune
  + Telescope will not travel in a straight line as it passes the planets because it will be affected by the gravity of the planets it passes (the path should dip toward the planet as it passes)
  + Once in its ending point the Telescope will begin to orbit the Sun and should be in-line with Earth

1. Explain what information in the tasks led you to choose this route.

Answers will vary.