Gravity and Orbits

Time of Lesson: 60-75 minutes

Content Standards Addressed in Lesson:

TEKS6.11B understand that gravity is the force that governs the motion of our solar system

TEKS6.11C describe the history and future of space exploration, including the types of equipment and transportation needed for space travel

NSES (1996) **Grades 5-8 – Content Standard D**

- Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system.

Scientific Investigation and Reasoning Skills Addressed in Lesson:

TEKS6.3A in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing

TEKS6.3B use models to represent aspects of the natural world such as an atom, a molecule, space, or a geologic feature

TEKS6.3C identify advantages and limitations of models such as size, scale, properties, and materials

TEKS6.3D relate the impact of research on scientific thought and society, including the history of science and contributions of scientists as related to the content

TEKS6.4A use appropriate tools to collect, record and analyze information, including computers

NSES (1996) **Grades 5-8 – Content Standard A**

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.

I. Student Prerequisite Skills/Understandings

1. A force is a push or a pull.
2. A basic understanding of the properties and locations of the eight planets of our solar system.

II. Objectives:

1. Students will identify advantages and limitations of models of the solar system.

2. Students will learn about the role of gravity in the solar system and how it affects the way planetary objects move in relation to each other.
3. Students will examine and judge scientific evidence and explanations using logical reasoning, experimental and observational testing.
4. Students will give accounts of the impact of scientists' contribution on current scientific thought and society.

III. Supplies Needed

Engage:

- 2 washers of equal size
- 1 m of string
- 1 piece of plastic pipe (with hole large enough to put string through)

Explore:

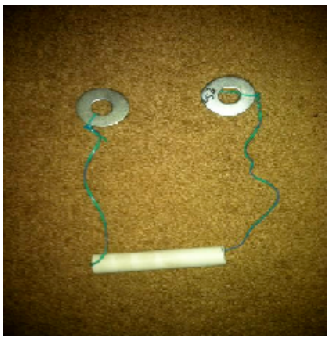
- 1 computer per pair

Elaborate:

- 1 calculator per pair

IV. Advanced Preparation

- Attach one washer to a string. Pass string through a piece of pipe. Attach second washer to end of string. See picture below.



5E Organization

Engage (5 minutes)

Content Focus: Gravity is a force that pulls on objects. The planets revolve around the Sun.

Teacher leads a brief demonstration (see set up above) to show how planets revolve around the Sun and gravity is a force that pulls. The washer represents a planet and the pipe represents the Sun. The teacher holds the system at one arm's length away from his/her body and holds the handle vertical. Holding onto the washer closest to him/her and using caution, the teacher rotates the pipe in a circular motion. The second washer will revolve in a circular motion. The teacher then pulls the washer that is closer towards his/her body and the other washer will revolve faster and have smaller radius of orbit.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• [As the teacher rotates the handle] What is the planet doing? • [As the teacher pulls on one of the washers and continues to rotate the handle] What happened to the revolution path of the planet? • What happened to the planet's speed?	• What could the string represent? Why? • How is this model similar/different from a real planet and the Sun?

✓ **Checkpoint:** Students can describe what they just observed.

Explore – History of the Study of Gravity (5 minutes)

Content Focus: Different scientists have contributed to the study of gravity. Human's conceptual understanding of gravity has changed over time.

Teacher leads a discussion on the history of the study of gravity. Galileo is introduced as developing the idea that all objects fall at the same rate when little air resistance is present. At his time, scientists viewed gravity as being unique to Earth. The teacher relates the demonstration to Galileo's view. Sir Isaac Newton's view on gravity is defined. The teacher describes Newton's idea of gravity being a force that behaves in similar ways throughout the universe. The teacher relates Sir Isaac Newton's views to the opening demonstration.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• Where have you heard of Galileo before? • Where have you heard of Sir Isaac Newton before? What is he famous for?	• If gravity was unique to earth, what would that tell you about the gravity on other planets? • In our demonstration what could have represented gravity? Why? • According to Galileo, if the washer represented a different planet, what would have to be different about our model? • What would Sir Isaac Newton think about our

	demonstration?

✓ **Checkpoint:** Students can relate Galileo's and Newton's ideas to the opening demonstration.

Explore – *Gravity and Orbits* PhET Simulation (30 minutes)

Content Focus: Gravity is the force that governs the motion of our solar system.
Investigation Skills: analyze data to formulate reasonable explanations, use a PhET simulation to represent aspects of the natural world, use computers to collect, record and analyze information, identify limitations of the PhET simulation

The Question of the Day, "How does gravity affect the motion of the planets?" is introduced. The teacher groups students in pairs and assigns each student to the role of either Driver or Navigator. Students are given 5 minutes to explore the *Gravity and Orbits* PhET simulation (see http://phet.colorado.edu/en/simulation/gravity-and-orbits). After five minutes, students share out what they have discovered. Activity sheets are passed out and students are given 30 minutes to complete their investigation. Students switch roles halfway through their investigations.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What do you notice about the path of the orbit? • What do you notice when you change the sizes of the objects? • What is the shape of the orbit? • What happens when you change the distance between the object? • What could you vary to change the time of orbit?	• What have you discovered the simulation can do? • What makes things crash? • If a force can't be felt, how do we know that it is there? • How is the work you are doing similar to the work of a scientist? • Based on your observations, describe how gravity affects the motion of different planets. • How would you define the word orbit using your simulation sheet as evidence? • How would you define gravity? • Why is gravity important to learn about?

✓ **Checkpoint:** Students have completed their activity sheets. Computers are collected.

Explain (20 minutes)

Content Focus: Gravity is the force that governs the motion of our solar system.
Investigation and Reasoning Skills: analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, identify advantages and limitations of models such as size, scale, properties, and materials

Teacher leads class discussion on the results and observations of the students' investigations. Students share their definitions for orbit and gravity. Students predict what would happen if gravity was not present and relate this to why gravity is important. Gravity force arrows are described. Students share ways they were able to change the time it took for the Earth to complete one revolution around the Sun and discuss how gravity changed. Teacher relates students' experiences to the Question of the Day. Limitations and advantages of using a model are described. Students explain how they would change the simulation to make it a better representation of our solar system. The teacher describes the GRAIL mission and its current goals, which are to map the differences in gravity across the moon's surface and use this information to understand how planets are formed.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What observations did you make about the path the Earth takes around the Sun? Moon around the Earth? • What did you notice when you turned off gravity in the simulation? • What could you vary on the simulation? • How could you change the time it took for the Earth to orbit the Sun? • If the mass of either object involved increases, what happens to the gravitational force arrows? • If the distance between the planet and the Sun increases, what happens to the gravitational force arrows? • What are some limitations/advantages of using a simulation?	• How did you define the word orbit? • How did you define the word gravity? • Why is gravity important to learn about? • What do you think the gravity force arrows represented? What do your observations tell you about gravity? • What relationship did you determine about how the size of the planet affects the gravitational force? • What relationship did you determine about how the distance from the Sun affects the planet's gravitational force? • How would you change the simulation to make it a better representation of the solar system? • Besides using a computer simulation, what else could you use to detect if gravity is present?

✓ **Checkpoint:** Students are able to communicate their conclusions and observations using the simulation as evidence.

Elaborate (5-10 minutes)

Content Focus: An object's mass remains constant everywhere in the solar system. An object's weight changes on different planets.

Students complete a short activity on how an object's weight changes on different planets. A more massive planet has a larger gravitational pull than a less massive planet. The students share their results. Careers that relate to space are discussed, such as, being an engineer or an astronaut. Students decide how they would spend NASA's budget if they were in charge of our nation's space program.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• If you were to travel into outer space, would your mass change? Weight? • [Using Jupiter as an example] How does Jupiter's mass compare with the Earth's? • What kinds of jobs do you think people interested in the solar system could do? • If you were in charge of NASA's spending, what would you focus on? Why?	• If different planets have different masses, how would gravity be different? • What is the difference between weight and mass? • If Jupiter has a larger mass, would gravity be greater or smaller on Jupiter?

✓ **Checkpoint**: Students completed the exercise for two planets and discussed their results. Students can distinguish between mass and weight. Different careers related to space and how the students would spend NASA's budget are discussed.

Evaluate

Use evaluations in attached documents.

Question of the Day

How does gravity affect the motion of the planets?

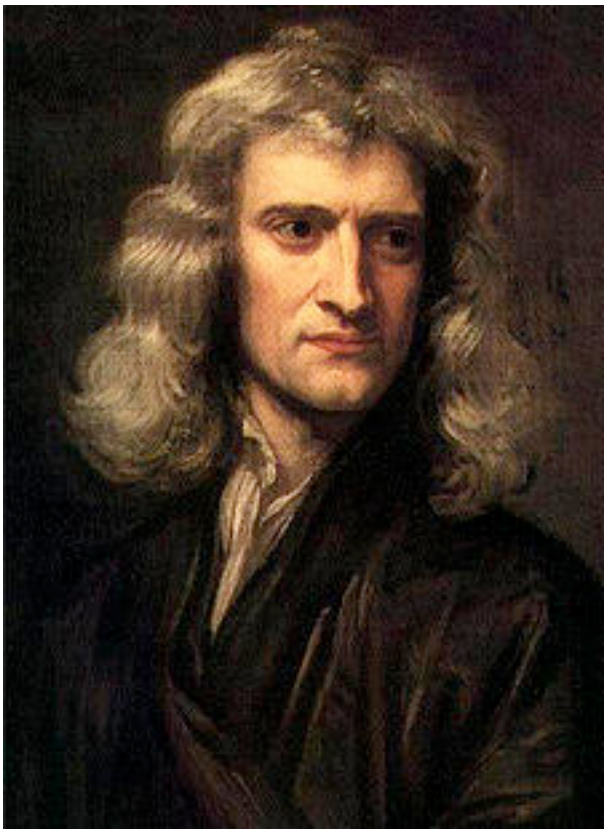


Photo of Sir Isaac Newton. Source: http://www.newton.ac.uk/art/portrait.html

Photo of Galileo Source: http://www.nmm.ac.uk/mag/pages/mnuExplore/PaintingDetail.cfm?ID=BHC2700

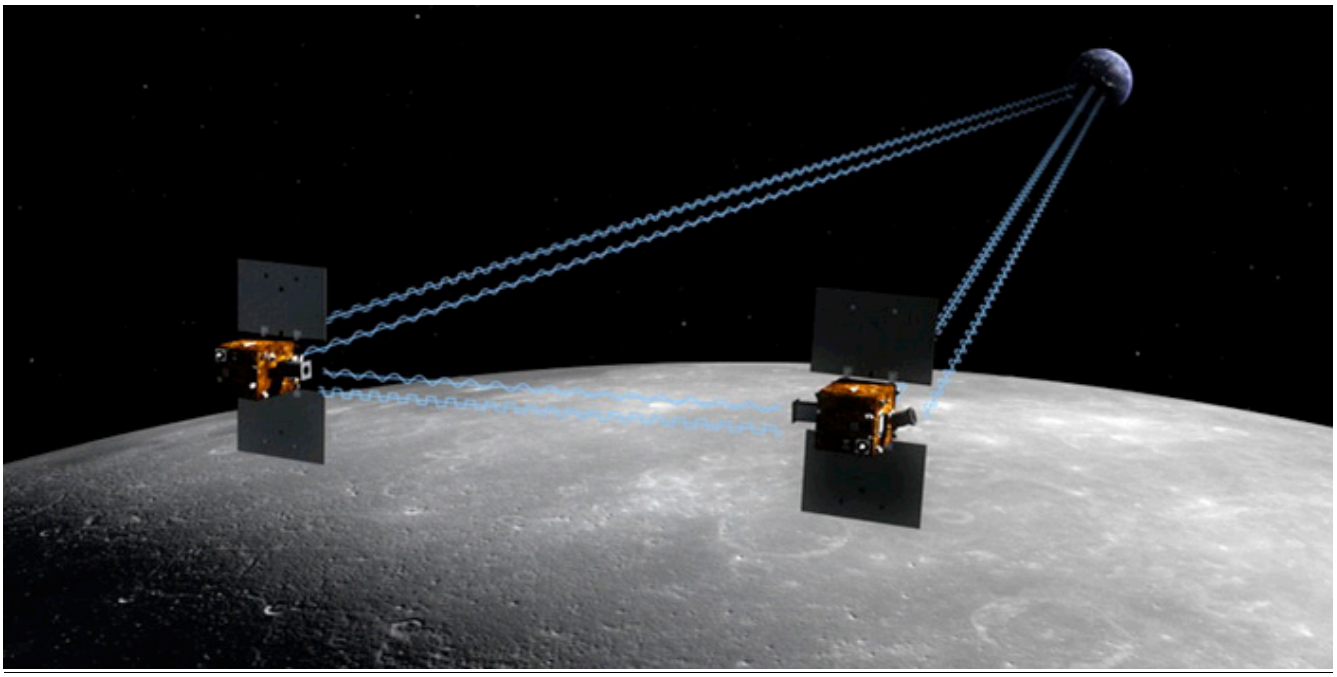


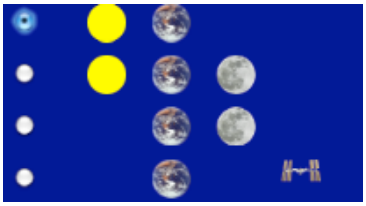
Photo of Gravity Recovery and Interior Laboratory Source:
http://solarsystem.nasa.gov/grail/missionoverview.cfm

Name: _____

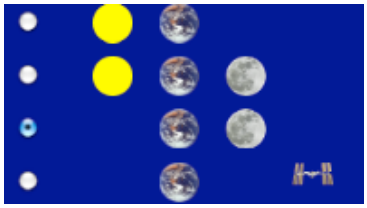
Gravity and Orbits PhET

Part I: Orbits

a) Draw the path of the Earth orbiting the Sun.



b) Draw the path of the Moon orbiting the Earth.



c) Based on your observations, what **similarities** and **differences** can you observe about the motion of the Earth (a) and the motion of the Moon (b)?

d) Based on your observations, how would you define the word "orbit"? Use (a) and (b) as your evidence.

Part II: What holds the Earth in orbit around the Sun and the Moon in orbit around the Earth? Explore the simulation to determine what keeps the Earth in orbit around the Sun and the Moon in orbit around the Earth.

a) What do you think the gravity force arrows represent?

b) What do you notice about the size of the "Gravity Force" arrows?

d) In what direction do the arrows point? What do you think this means?

e) Based on your observations, how would you define the word "gravity"?

Part III: Gravitational Force between the Earth and the Sun

a) It takes 365 days for the Earth to complete one revolution around the Sun. Find **three** different ways to change the **number of days** it takes for the Earth to complete one revolution around the Sun.

Method	How many days did it take to complete one revolution?	What did you do?	What happened to the gravitational force arrows?	Observations
1				
2				
3				

b) In a few sentences, what can you conclude about how the **size** of a planet and its **distance** from the Sun affects its orbit?

Part IV: Gravitational Force between Different Planets and the Sun

a) Venus is called Earth's "sister planet" because it is almost the same size (mass and diameter) as Earth. Venus is closer to the Sun, what can you say about the following? (Circle the word you think is correct)

- The Sun has a **stronger/weaker** gravitational pull on Venus than it does on Earth.
- Venus has a **longer/shorter** period of revolution around the Sun when compared to Earth's period of revolution around the Sun.

b) Jupiter is has a much larger mass than the Earth and is farther away from the Sun. What can you say about the following?

- Jupiter has a **longer/shorter** period of revolution around the Sun when compared to Earth's period of revolution around the Sun.

Name: _____

SHOW OFF WHAT YOU KNOW!

1. Gravity is a(n) _____ force that acts between two or more objects. Gravity exists _____ in the universe
a. repulsive, everywhere
b. attractive, in some places
c. repulsive, in some places
d. attractive, everywhere

2. As the distance between two masses decreases, the gravity force between them
a. increases
b. decreases
c. remains constant

3. How did Galileo and Sir Isaac Newton differ in their views of gravity?
a. Galileo thought that gravity was unique to Earth, while Newton saw it as universal.
b. Galileo thought that gravity was a push, while Newton thought it was pull.
c. Galileo found that gravity affects objects with the same force, while Newton saw that gravity depends on the mass of an object.
d. Galileo and Newton's views did not differ.

4. Astronaut Luke Starkiller wants to travel to the far away galaxy. He weighs 250N (Newtons) on earth. The table to the right shows the weight conversions for earth and two planets in that galaxy. In which planet will astronaut Starkiller feel the heaviest?
a. Yavin IV
b. Yavin II
c. Both Yavin IV and Yavin II
d. Earth

Planet	**Conversion factor**
Earth	× 1.00
Yavin IV	×0.85
Yavin II	×0.20

Name: _____

What's your weight on other planets?

Due to the different gravitational pulls each planet has, you would weigh differently based on what planet's surface you are on. Assume you weigh **300 Newtons**. *A Newton is a unit for measuring weight.*

Planet	Conversion
Mercury	x 0.378
Venus	x 0.905
Earth	x 1
Mars	x 0.379
Jupiter	x 2.529
Saturn	x 1.066
Uranus	x 0.903
Neptune	x 1.096

Formula:

300 Newtons x conversion factor (see table above) = your weight on another planet

1) Planet 1: _____

a) Do you think you will weigh more or less on this planet? Why?

b) Calculate your weight on this planet.

2) Planet 2: _____

a) Do you think you will weigh more or less on this planet? Why?

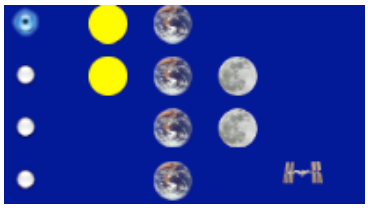
b) Calculate your weight on this planet.

Name: _____KEY_____

Gravity and Orbits PhET

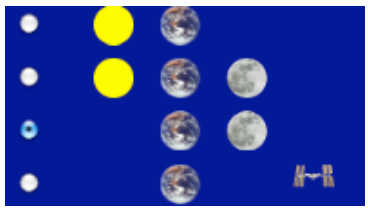
Part I: Orbits

a) Draw the path of the Earth orbiting the Sun.



It should be elliptical in shape, the simulation shows it a bit more circular than in reality

b) Draw the path of the Moon orbiting the Earth.



Although in principle it should be elliptical, a circular path of the moon around the earth is a sufficient first approximation

c) Based on your observations, what **similarities** and **differences** can you observe about the motion of the Earth (a) and the motion of the Moon (b)?
Similar: Both revolve around bigger object, elliptical, shorter the distance the shorter the speed, gravity force
Different: Moon's path is more circular and shorter radius of revolution, greater speed

d) Based on your observations, how would you define the word "orbit"? Use (a) and (b) as your evidence.
It is the path followed by an object revolving around another. It can be elliptical or circular.

Part II: What holds the Earth in orbit around the Sun and the Moon in orbit around the Earth? Explore the simulation to determine what keeps the Earth in orbit around the Sun and the Moon in orbit around the Earth.
a) What do you think the gravity force arrows represent? **The direction where the arrows point is the direction of the pull and the length is the strength (i.e. longer arrow, greater force)**

b) What do you notice about the size of the "Gravity Force" arrows relative to each other? **As the objects come to a closer distance, the arrows get longer**

c) In what direction do the arrows point? What do you think this means? **The direction of the gravity force. That there is gravity force between two objects**

d) Based on your observations, how would you define the word "gravity"?
It is a pull or force between two objects. It depends on the distance between the objects

Part III: Gravitational Force between the Earth and the Sun

a) It takes 365 days for the Earth to complete one revolution around the Sun. Find **three** different ways to change the **number of days** it takes for the Earth to complete one revolution around the Sun.

Method	How many days did it take to complete one revolution?	What did you do?	What happened to the gravitational force arrows?	Observations
1	It took less time	Place the Earth closer from the Sun	Got longer	The time it took for one revolution went down
2	It took more time	Make the velocity arrow longer	Started getting shorter	The path changed (different orbit). Took more time
3	It took less time	Increase the size of the sun	Got longer	Took less time for one revolution

(For opposite actions the effect on revolution time is also opposite)

b) In a few sentences, what can you conclude about how the **size** of a planet and its **distance** from the Sun affects its orbit?

The shorter distance, means there is a smaller orbit. The larger the planet, the greater the gravity force (longer arrow) but the orbit remains the same.

Part IV: Gravitational Force between Different Planets and the Sun

a) Venus is called Earth's "sister planet" because it is almost the same size (mass and diameter) as Earth. Venus is closer to the Sun, what can you say about the following? (Circle the word you think is correct)

- The Sun has a **stronger/weaker** gravitational pull on Venus than it does on Earth.
- Venus has a **longer/shorter** period of revolution around the Sun when compared to Earth's period of revolution around the Sun.

b) Jupiter is has a much larger mass than the Earth and is farther away from the Sun. What can you say about the following?

- Jupiter has a **longer/shorter** period of revolution around the Sun when compared to Earth's period of revolution around the Sun.

Answer Key for "What's your weight on other planets?"

Planet	Will you weigh more or less?	Why? (Samples answers)	Your calculated weight.
Mercury	Less	Mercury is much smaller than the Earth.	(300)(0.378) = 113.4
Venus	Less	Venus is smaller than the Earth.	(300)(0.905) = 271.5
Earth	Same	This is our control factor.	(300)(1.0) = 300.0
Mars	Less	Mars is smaller than the Earth.	(300)(0.379) = 113.7
Jupiter	More	Jupiter is much larger than the Earth and thus has a larger gravitational force.	(300)(2.529) = 758.7
Saturn	More	Saturn is larger than the Earth.	(300)(1.066) = 319.8
Uranus	Less	Uranus is less dense and much farther from the Sun.	(300)(0.903) = 270.9
Neptune	More	It is larger than the Earth.	(300)(1.096) = 328.8

SHOW OFF WHAT YOU KNOW Answer Key:

1. D- attractive, everywhere
2. A- decreases
3. A - Galileo thought that gravity was unique to Earth, while Newton saw it as universal.
4. D- Earth