

Gravitational Force Unit plan

Mary Webster

Physical Science in Motion

Grade Level: 8
with 25% ELL

Subject: Science **Student population:** Urban school

Student Expectations:

Students will be able to construct an argument using evidence to support the claim that gravitational interactions in a large-scale system (e.g., galaxies and solar system) are attractive and depend on the masses of and distance between interacting objects.

Student Goals:

Students will have guided inquiry labs, whole group, small group and individually throughout this unit. The students will use models to explain the phenomena, use evidence to support their own claim (CER), students will also make predictions based on the explanation of the phenomena as they move through the unit.

Relevance to students' lives, interests, environment, background, culture:

Watching the planets move around the Sun helps us see that gravity is more than just what keeps our feet on the ground—it's a force that shapes the motion of everything in space and on Earth. Understanding how gravity depends on mass and distance connects to real life experiences, like why things fall, how we jump, or even how we stay in orbit on rides and transportation systems.

Guiding Question:

What factors impact gravitational interactions in a large system, such as our solar system?

Depth of Knowledge:

Level 3 - Explaining phenomena in terms and concepts, CER, connecting ideas, reasoning, planning, using evidence and in most cases to "explain their thinking."

Level of Inquiry:

Students will use level one inquiry where the students will confirm the principle of gravity with a predetermined result.

Students will also use level two inquiry where the students will investigate a teacher presented question.

Standards addressed:

8th Grade Science

8.PS2.3: Construct an argument using evidence to support the claim that gravitational interactions in a large-scale system (i.e., galaxies, and solar system) are attractive and depend on the masses of and distance between interacting objects.

SEP:

Knowledge and skills- Developing and using models to develop explanations for phenomena, to go beyond the observable and make predictions or to test designs.

Using mathematical and computational thinking as tools to represent variables and their relationships in models, simulations, and data analysis in order to make and test predictions.

CCC:

Scale, proportion, and quantity integrate measurement and precision of language.

What words do the students need to know (prior knowledge)?

Argument- Evidence and reasoning laid out in order to convince others that a particular position or statement is the correct one.

System-A series of parts that interact to form a complex whole

Gravity-The force that causes objects with mass to attract one another

Mass-A measure of how much matter is present in a substance.

Interacting objects- Objects that affect one another.

Distance- A measure of how far apart two objects are.

Unit Vocabulary

Distance- A measure of how far apart two objects are.

Force- A push or pull that can change the motion of an object.

Galaxy- A large grouping of stars in space.

Gravitational pull- The attraction between two objects due to the invisible force of gravity; the gravitational pull from the Moon is primarily responsible for the tides that form on Earth.

Gravity- The force that causes objects with mass to attract one another.

Mass- A measure of how much matter is present in a substance.

Motion- The change in an object's position with respect to time and in comparison, with the position of other objects used as reference points.

Orbit- A curved path followed by a satellite as it revolves around an object.

Solar system- A star and the group of planets and other celestial bodies that are held by its gravitational attraction and revolve around it.

Weight- The heaviness of an object; force of gravity on mass = weight

Background information (teacher):

A vector is a quantity that has magnitude (a number) and direction, like the strength of the wind blowing in a certain direction. A scalar is a quantity that has only magnitude but no direction. Force is a vector because it has both a size (magnitude) and direction. You feel a force (push or pull) in a certain direction. Because of this, all force fields (magnetic, electric, and gravitational) are vector fields.

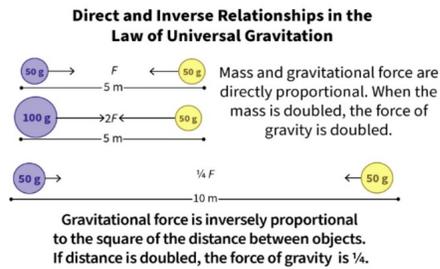
Gravity and electromagnetic forces have the ability to act at a distance. This means that objects can interact and show motion based on the interaction of their force fields, even if the objects are not in direct contact. Gravity is one of the fundamental forces of nature. In 1687, Sir Isaac Newton introduced the law of universal gravitation.

It states:

$$F_g = G \left(\frac{m_1 m_2}{d^2} \right)$$

Where F_g is the gravitational force between two objects, G is the gravitational constant, m_1 and m_2 are the masses of the two objects, and d is the distance between the two objects. This law says that any two objects with mass exert a gravitational force on each other. The force on each object has the same magnitude. The magnitude is proportional to the product of the objects' masses. Gravity has the ability to act at a distance, which means objects can interact and show motion based on interaction of their force fields even if the objects are not in direct contact. It is inversely proportional to the square of the distance between them. For example, the enormous mass of the Sun creates such a large gravitational field that it can pull the entire solar system around it. The gravitational fields of planets pull moons in orbit. Jupiter, the largest planet, has such a large

gravitational field that it pulls more than 60 moons in orbit. Our small rocky planet, Earth, pulls only one moon in orbit.



The gravitational constant was measured by Henry Cavendish some 71 years after Newton's death. Cavendish used an instrument called a torsion balance, which allowed him to measure the attraction between small lead balls. Since gravity is a very weak force, many precautions had to be taken to minimize disturbances caused by other forces such as air currents. In 2007, more precise measurements determined that the gravitational constant equaled 6.693×10^{-11} cubic meters per kilogram second squared. The gravitational constant does not appear to vary over the age of the universe.

Gravity has several important characteristics. It has unlimited range. This means that all objects in the universe are attracted to all other objects in the universe. Since the force decays with distance squared, the attraction of very distant objects can usually be ignored unless they have a large mass. Gravity is a very weak force. So, although you attract the pencil on your desk and it attracts you, the force between you and the pencil is too small to make the pencil move. On the other hand, since Earth has a large mass, the pencil is attracted to Earth; if it is dropped, it will fall. Earth is also attracted to the pencil, but since the pencil's mass is so small, the movement of Earth towards the pencil is too small to be noticed. Gravity is always attractive, never repulsive.

Gravity has an important role in the appearance and function of the universe. Scientists propose that immediately after the big bang, matter was unevenly distributed throughout the expanding universe. Gravitational attraction between atoms allowed the formation of clumps of matter, which eventually formed celestial bodies. The orbits of planets are governed by gravitational attraction between stars and planets and among planets. Moons are captured by planets when relatively slow-moving objects pass too closely to a planet. Astronomers infer the existence of invisible bodies based on their effects on observable orbits.

Learning activities:

Engage: 1 day

Accessing Prior Knowledge (10 minutes):

Materials:

4 pictures printed and posted, teacher created presentation with student directions.

Instructions:

Students will dialogue with classmates about their understanding of gravity through a four-corners discussion.

Pictures will be posted at four corners of the classroom for the students to be able to see from their seat.

Students are asked to look at the four corners and think about:

Which corner image best explains how celestial objects are held in orbit within our solar system?

Image 1:

The Sun's gravity affects all of the planets equally, and they move randomly throughout the solar system.

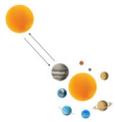


Image 2:

Earth is the source of gravity within our solar system.

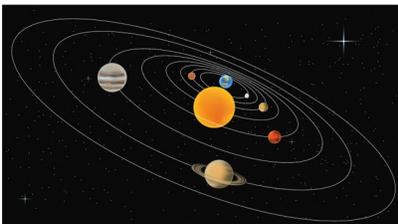


Image 3:

The Sun's gravity holds each planet in a very precise location along their orbit.

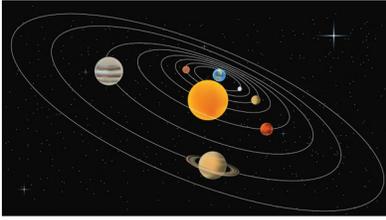


Image 4: Gravity plays no role in the solar system. It is only true for objects on



Earth.

Students will decide at their table which corner image best explains how celestial objects are held in orbit within our solar system. Students will write down their best guess and why that is the best answer on their note catcher. (1-2 minutes)

Students will physically move to the corner of the room, bringing their notes, with the picture that best answers the question:

Which corner image best explains how celestial objects are held in orbit within our solar system?

Students will discuss with each other what they wrote and why they chose this picture.

2-5 minutes of discussion.

Misconceptions and correct answer:

Image 1: Students may not realize that the Sun's gravity affects each of the planets in a precise way. This interaction determines where the planets fall in their distances from the Sun.

Image 2: Students may not realize that Earth is not the source of gravitational forces within the solar system. The Sun has the most mass of any object within our solar system. Therefore, its gravity is much greater than any other object within our solar system.

Image 3: This is the correct answer.

Image 4: Students may think that gravity only exists on Earth. Gravity does play a role in the motion of objects on Earth, but it is also found between objects in space.

Phenomena 20 -30 minutes:

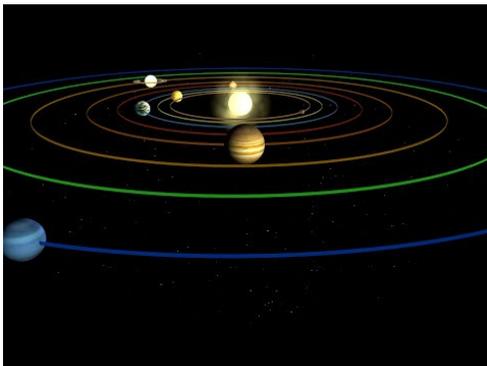
Students will demonstrate their understanding of science ideas and explain how they relate to their previous learning and everyday experiences.

Anchoring Phenomenon:

Students will view a video of the solar system and the planets' motion around the Sun to learn about how gravitational interactions are attractive and depend on the masses of and distances between interacting objects. Students should build on their knowledge and understanding of the phenomenon as they move through the different activities in this unit. Phenomena will be referred back to frequently through the unit to solidify and confirm understanding.

After students watch the video (repeating as many times as necessary... video is only 13 seconds long) teacher will lead a class discussion answering the following questions one at a time. As questions are answered, a volunteer student will write down the notices and wonders on a large post it or similar poster type visual. The phenomena will be referred back many times during this unit.

Gravity Dance



1. How would you describe what you observe in the video?

(notices)

2. Why is the Sun the object at the center of the motion?
3. What determines the path of the planets in the solar system?

(wonders)

Explores:

Formative questions to ask during or after all the explore activities:

Where do you see scale, proportion, and quantity in this activity?

Where have you seen scale, proportion, and quantity before this activity?

Where do you see scale, proportion, and quantity outside the classroom?

Where do you think you will see scale, proportion, and quantity in other science lessons?

How did the model help to explain the phenomenon?

What were some limitations of the model?

How could the model be improved so that it is a better representation of the phenomenon?

3 lab type investigations:

Explore 1(1 hour or class period):

Students will use models to observe the effects of mass on the gravitational force between interacting objects in a system.

Materials:

Printed 1 Student Handout: Mass and Gravitational Force (per student)

1 Single-size bed sheet, preferably of a more elastic fabric (per class)

*2 Croquet balls (per class) 1 Table-tennis ball (per class)

*Other types of balls may be substituted for the croquet and table-tennis balls if these are not readily available; however, it is important that one be more massive than the other, such as a bearing and a marble or a pool ball and a plastic ball with holes.

Procedure and Facilitation Points:

For test 1, have four students pull the edges of the sheet to make it taut.

Place a croquet ball in the center of the sheet.

You can have another student do this, or you can do this for the class.

Have the students write the observations that they make.

The ball should sink a little, forming an indentation in the sheet.

Add the table-tennis ball to the sheet a small distance away from the croquet ball.

The table-tennis ball should move toward the croquet ball.

For test 2, place the table-tennis ball on the sheet first and then the croquet ball.

Have the students write observations.

For test 3, use both croquet balls, and have students make observations.

Be sure that students understand the difference between mass and weight. Weight depends not only on mass but also on the effect of gravity on the object.

Students have a lab write-up to use during the entire activity.

Exit ticket suggestion:

How does this activity relate to/ give a model of the solar system and/ or gravity?
Use the EQ as a reference.

What factors impact gravitational interactions in a large system, such as our solar system?

Explore 2 (1-2 hours): Scientific exploration- Gravitational forces between objects

Students use a PhET simulator to model system interactions between gravity and the mass of objects. Students use evidence collected from the model system and scientific reasoning to construct a scientific explanation about gravitational forces.

Materials: PhET activity link and instructions

[Gravity Force Lab - Gravitational Force | Inverse Square Law | Force Pairs - PhET Interactive Simulations](#)

Essential Question for activity: What factors affect the gravitational pull of two massive objects?

During this activity, students will explore scale, proportion, and quantity.

Explore 3 (1-2 hours): Gravitational Forces in space

Students use a PhET simulator to explore gravitational forces in space and gather evidence that gravitational attractions are dependent on mass.

Materials: PhET activity link and instructions

[Gravity and Orbits - Gravitational Force | Circular Motion | Astronomy - PhET Interactive Simulations](#)

Students will have a lab sheet to record their findings.

Students will complete their own CER based on the PhET and how they manipulated the simulation.

Explain (1 hour or class period):

Students will use science ideas and evidence to explain what they've learned and make sense of observations and experiences.

Picture vocabulary activity

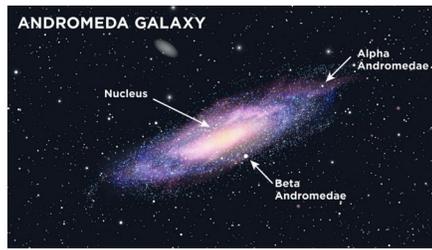
Reading Stemslopedia with linking literacy prompts

Evaluate (1 hour or class period):

CER:

Scenario: Our solar system is a part of the Milky Way galaxy. The next closest galaxy to us is the Andromeda galaxy. The center, or nucleus, of the Andromeda galaxy is millions of solar masses. Solar mass is a unit of measure used for very massive objects in the universe. Our Sun is one solar mass. Two of the stars that orbit the nucleus of the Andromeda galaxy are Alpha Andromedae and Beta Andromedae.

External Data



Objects in the Andromeda Galaxy	Mass (Solar Mass)
Alpha Andromedae	5.4 Solar Mass
Beta Andromedae	3 Solar Mass
Andromeda galaxy nucleus	140 million Solar Mass

Prompt: Write a scientific explanation about why Alpha Andromedae and Beta Andromedae both orbit the Andromeda galaxy's nucleus and how this translates into how our solar system moves in the Milky Way.

Short answer:

1. How can the gravitational force between two objects decrease?
2. The table below shows four examples of pairs of objects, their masses, and the distances between them. In which example is the gravitational force of attraction between the two objects the greatest?

Example	Mass 1 (kg)	Mass 2 (kg)	Distance (km)
1	100	200	20
2	100	200	10
3	50	100	20
4	50	100	10

3. If Neptune's mass were reduced, what could be done to maintain the same force of gravitational attraction between Neptune and the Sun?

Multiple choice assessment:

[Evaluate Multiple Choice Gravitational Forces_SH.pdf](#)

Elaborate (1-2 hours or class period if time is available):

4 Corner Debate with original pictures in 4 corners of room (APK activity)

Engineering Design Problem:

The Problem The planets in the solar system move forward in their orbit at just the right speed to balance the Sun's gravitational pull. If the planets moved slower,

scientists theorize that the planets would fall into the Sun, causing a huge problem. Since you cannot go into the solar system to test this gravitational pull, you can make a model instead. You are tasked to build a model rocket and test it against the effects of gravity on Earth while also considering how gravity acts in similar or different ways in the solar system.

Criteria and Constraints

1. Build a model rocket out materials such as paper, straws, PVC pipes, rubber bands, etc.
2. Use the compressed air from stomping on a 2 L bottle connected to your rocket, or the chemical reaction of a heartburn tablet, to launch your rocket.
3. Test your rocket by conducting three trials, launching it at 30, 45, 60, 75, and 90 degrees in each trial.
4. Record the distance traveled in meters and the time in seconds that the rocket was moving through the air.
5. Write two paragraphs comparing your rocket model testing to the Sun's gravitational pull on the planets in the solar system

Students will use the engineering design process to complete this activity and the activity will be graded on the following rubric:

Engineering Design Process Student Rubric

Category	3	2	1	0
Brainstorm	The student listed multiple brainstormed ideas.	The student listed a couple brainstormed ideas.	The student listed only one brainstormed idea.	The student did not attempt to brainstorm a solution.
Plan	The plan could successfully solve the problem.	The plan has some issues that would make it unlikely to fully solve the problem.	The plan would not solve the problem at all.	No plan was created.
Build and Test	The student successfully built their planned solution, tested it, and identified areas for design improvement following the test.	The student successfully built their planned solution and tested it but did not identify areas for design improvement.	The student successfully attempted to build their planned solution but did not test it.	The student did not attempt to build.
STEM Skill: Critical Thinking	The student presented an evidence-based solution to the posed problem or scenario.	The student presented a solution to the posed problem or scenario, but they did not include any evidence from research.	The student presented a solution that did not align with the posed problem or scenario.	The student did not present any solution to the posed problem or scenario.
STEM Skill: Promptness and Time/Resource Management	The student completed work on time and planned and utilized resources or materials appropriately with no waste.	The student completed work on time and utilized some resources appropriately with little waste.	The student completed work on time but did not plan out the use of resources or materials, resulting in waste.	The student did not complete the work on time and wasted resources or materials.