Gravitational Forces

Scope Planning and Overview

Student Wondering of Phenomenon

Why do objects on Earth not float off into space?

Student Expectations

The student will–

- use Newton's law of universal gravitation, $F=Gm_1m_2/r^2$, to calculate the gravitational forces, mass, or distance separating two objects with mass, given the information about the other quantities.

Scope Overview

In this instructional unit, students explore the principles of gravitational forces using Newton's law of universal gravitation. Through hands-on experiments and calculations, they examine the relationship between mass, distance, and gravitational pull between celestial objects, contextualizing these concepts in space travel scenarios. This approach helps students understand and apply complex concepts of scale, proportion, and quantity, enhancing their ability to engage in evidence-based argumentation and problem-solving related to cosmic gravitational phenomena.

Scope Vocabulary

The terms below and their definitions can be found in Picture Vocabulary and are embedded in context throughout the scope.

Gravitational force

A force of attraction between two masses

Gravity

A mutually attractive physical force of nature that causes two bodies to attract each other

Newton's law of universal gravitation

The law stating that every piece of matter is attracted to every other piece of matter; the force is directly proportional to their masses but inversely proportional to the square of the distance between them.

Notes

Engage Activity Summaries

APK

Accessing Prior Knowledge: : Fact or Fiction

In this activity, students respond to statements about universal gravitation by moving to areas of the classroom designated as “Fact” or “Fiction.” This physical movement helps visualize student understandings and misconceptions about gravitational concepts, such as the differences between mass and weight, and the universal nature of gravity. The activity is interactive and diagnostic, aimed at identifying and later addressing common misunderstandings, without being graded.

SP

Scope Phenomenon

In this activity, students watch a video featuring floating furniture to explore how gravity influences object acceleration towards Earth’s center. After viewing, they engage in a structured “Think, Pair, Share” exercise to discuss and deepen their understanding of gravitational effects, using the “Floating Furniture” handout for guidance. The activity fosters collaborative learning and critical thinking, as students pair up through various creative strategies to discuss and answer key questions about gravity’s role in everyday phenomena.

Explore Activity Summaries

Explore 1

Activity - Gravity Rules

In this activity, students explore gravitational forces between celestial objects and the impact of space travel on mass versus weight. They engage in hands-on experiments using balls of varying masses and a stretchy fabric setup to simulate gravity. Students calculate gravitational forces using provided data and engage in evidence-based argumentation to assess reasoning, explanations, and solutions related to gravitational phenomena. This practical application helps students understand concepts of scale, proportion, and quantity in a cosmic context.

Notes

Gravitational Forces

Accessing Prior Knowledge: Fact or Fiction

Activity Preparation

Students will listen to prompts about universal gravitation and communicate if they feel the prompts are fact or fiction by walking to the designated sides of the classroom. This element is designed to uncover student misconceptions. It should not be taken for a grade.

Materials

Activity Files

- Universal Gravitation Fact or Fiction (per teacher)

Reuseable

- None

Consumable

- None

Preparation

- If not assigning the APK digitally, print one Universal Gravitation Fact or Fiction prompt sheet to read aloud to your students.

Procedure and Facilitation

Activity

Fact or Fiction

1. Designate one side of your room as the Fact side of the room and the other side as Fiction. Instruct students to move to the side of the room based on if they think the prompt is fact or fiction.
2. Read the prompt and allow students to move to different sides of the room.
3. Before reading the next prompt allow students to move back to their starting point.
4. Repeat with another prompt.

CLASSROOM MANAGEMENT TIP

Project the prompts as well as reading them aloud. Provide some visual images to support comprehension of the prompts.

Identifying Misconceptions

- Prompt 1 - Fiction. Students think that gravity exists only in situations where it can be felt.
- Prompt 2 - Fiction. Students mistake weight and mass. Weight can change due to gravity. Mass remains constant.
- Prompt 3 - Fact. Students do not realize that gravity is a mutually attractive force and that the moon's gravity causes ocean tides.

CLASSROOM MANAGEMENT TIP

Although some students will be very eager to know if they are correct, consider waiting until the end of the scope to return to this activity to confirm correct responses.

Notes

Notes

Gravitational Forces

Scope Phenomenon

Activity Preparation

Students will watch a video of floating furniture to learn about how gravity causes all objects to accelerate toward the center of Earth. Students should build on their knowledge and understanding of the phenomenon as they move through the different activities in this scope.

Materials

Printed Material

- 1 Student Handout: Floating Furniture (per student)

Reusable

- None

Consumable

- None

Preparation

- If not assigning the activity digitally, print one Student Handout per student.
- Prepare to project the Student Handout.
- Brainstorm additional questions you may want to discuss beyond the Student Handout during the activity.

Procedure and Facilitation

ACTIVITY TIP

Post the Student Wondering Question: Why do objects on Earth not float off into space?Prompt students to explain what they think they know about gravity in as much detail as possible. Challenge them beyond any simple answers; ask "why?", and "how do you know?", and "can you give me an example?" etc. to get them thinking.

Activity

1. Distribute the Student Handouts.
2. Show students the video.
3. Ask students a question from the Student Handout.
4. **Think**: Allow students some time to think of answers.
5. **Pair**: Pair students. Sample partnering strategies include the following:
   a. Shoulder partner – Pair each student with one they sit next to.
   b. Name shares – Pair students whose names start with the same letter.
   c. Birthday months – Pair students with birthdays in the same month.
   d. Awkward school dance – Have students stand, looking at their feet, and begin walking around the class with their eyes on their feet. Call time, and have students look up. Whomever they make eye contact with first is their partner.
6. **Share**: Instruct students to take turns sharing their answers with their partners. Encourage students to build on each other's thoughts. Here's how to begin the conversation:
   a. The person with the next birthday will share first. For each additional question, think of a random way to determine who will share first.
7. Once students have discussed all of the questions with their partners, give them time to fill out their Student Handouts.

8. Introduce students to the Student Wondering of Phenomenon question below:
    a. Why do objects on Earth not float off into space?
9. Let students know that, as they move through the scope, they will be doing a number of activities to help them answer the Student Wondering of Phenomenon question and to learn the information that is needed to describe the events in the Scope Phenomenon.
10. When the scope is completed, have students review the Scope Phenomenon. As you lead them in answering the question, encourage them to use the information that they learned throughout the scope.

ACTIVITY TIP

Record student responses and post. Add additional thoughts and ideas about gravitational forces as you progress through course.

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Gravitational Forces

Explore 1: Activity - Gravity Rules

Activity Preparation

Timestamp *45 minutes–1 hour*

In this activity, students will explore and calculate gravitational forces between celestial objects as well as the effects of space travel on mass vs. weight.

Materials

Printed

- 1 Student Handout: Gravity Rules (per student)

Consumable

- 2 Rolls of tape, optional (per teacher)

Reusable

- 1 Square of stretchy fabric (e.g., elastane), 0.5 m x 0.5 m (per group)
- 1 Frame (e.g., large bowl, plastic storage container, or shoebox) (per group)
- 1 Large rubber band that fits the frame (per group)
- 1 Ball set (per group)
  - 1 Golf ball
  - 1 Table-tennis ball
  - 1 Marble

Preparation

- Print out the Student Handout for each student.
- Divide students into groups of three or four, depending on the class size.
- Use a rubber band or tape to attach the fabric to the frame so that it is taut but able to stretch.
- Test the fabric to be sure that it will stretch and then return to a flat surface.

Connections

SEP Connection

Engaging in Argument from Evidence

During this activity, students will engage in argumentation from evidence to identify strengths and weaknesses in a line of reasoning, to identify best explanations, to resolve problems, and to identify best solutions.

While students work through this activity, they should do the following:

- Engage in argumentation from evidence to identify strengths and weaknesses in a line of reasoning
- Engage in argumentation to identify the best explanations
- Engage in argumentation to resolve problems
- Engage in argumentation to identify the best solutions

Once students have completed this activity, ask these questions:

- Is the reasoning supported by evidence?
- How can we evaluate the different explanations to find the best explanation?
- How does the resolution or solution here compare to real-world resolutions?

Give students two different arguments related to a phenomenon in the activity, one with evidence and one without, and then ask students to identify which argument is more scientific and why.

CCC Connection

Scale, Proportion, and Quantity

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

Ask students the following questions:

- 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?

Procedure and Facilitation

1. Distribute a Student Handout to each student.
2. Students will begin by feeling the masses of the golf ball, table-tennis ball, and marble and ranking them by mass.
3. Students will place each object in the center of the fabric and look at how much the fabric stretches. Caution students to release the object only after it makes contact with the fabric. They will rank the objects based on how much they stretch the fabric.
4. Students will place the object that stretched the fabric the most in the center of the fabric and place one of the other objects at the edge of the fabric. They will record the motion of the object on the Student Handout.
5. Next, students will place this object approximately halfway between the edge and the object that is at the center; then, they will place it approximately three-quarters of the way between the edge and the center object. They will record the motion of the object each time.
6. Students will remove the objects from the fabric.
7. Tell students to choose four planets from the Solar System Information table on the Student Handout.
8. Have students use the information in the Solar System Information table to calculate and fill out the gravitational forces for their four planets in the Gravitational Force Calculations table on the Student Handout.

ACTIVITY TIP

Follow up with some questions about how the spheres used in this Explore might behave on other planets in the Solar System. Ask what a baseball game, dance recital, swim meet or sneeze might look like on/ in other planets' gravitational force.

ACTIVITY TIP

ave the class vote on one planet to do together as an example. Model how to calculate the force.

Phenomenon Connection

Once students have completed this learning activity, revisit the Student Wondering of Phenomenon and use the following questions to guide a class discussion.

Why do objects on Earth not float off into space?

- How does this activity connect to or answer the question above?
- How does this activity change your thinking about the phenomenon?
- Do you have any additional questions or observations about the connection between the phenomenon and the activity?

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Scope Resources and Assessment Planner

Scope Resources

Explain

- ☐ **Picture Vocabulary**
  A slide presentation of important vocabulary terms along with a picture and definition.
- ☐ **STEMscopedia**
  Reference materials that includes parent connections, career connections, technology, and science news.
- ☐ **Linking Literacy**
  Strategies to help students comprehend difficult informational text.

Elaborate

- ☐ **Math Connections**
  A practice that uses grade-level appropriate math activities to address the concept.
- ☐ **Reading Science - Measuring the Universal Gravitational Constant**
  A reading passage about the concept, which includes five to eight comprehension questions.
- ☐ **Engineering Connections**
  A creative, kinesthetic extension into engineering and design that uses concepts addressed in the scope.

Evaluate

- ☐ **Claim-Evidence-Reasoning**
  An assessment in which students write a scientific explanation to show their understanding of the concept in a way that uses evidence.
- ☐ **Open-Ended Response Assessment**
  A short-answer and essay assessment to evaluate student mastery of the concept.
- ☐ **Multiple Choice Assessment**
  A standards-based assessment designed to gauge students' understanding of the science concept using their selections of the best possible answers from a list of choices

Intervention

- ☐ **Guided Practice**
  A guide that shows the teacher how to administer a small-group lesson to students who need intervention on the topic.

Notes

Assessment Planner

Use this template to decide how to assess your students for concept mastery. Depending on the format of the assessment, you can identify prompts and intended responses that would measure student mastery of the expectation. See the beginning of this scope to identify standards and grade-level expectations.

Student Learning Objectives	What Prompts Will Be Used?	What Does Student Mastery Look Like?
use Newton's law of universal gravitation, $F=Gm_1m_2/r^2$, to calculate the gravitational forces, mass, or distance separating two objects with mass, given the information about the other quantities.		