

More Attractive Than You Think

Universal Law of Gravity

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Grade Level	11th – 12th Grade	**Time Frame**	160 minutes
Subject	Science	**Duration**	4 class periods
Course	Physics		

Essential Question

What variables affect the force of gravity? Why do objects attract each other? How do graphs show the relationships between different variables?

Summary

In this lesson, students investigate what factors affect the force of gravity and use plotted data to determine graphically how each variable is related to the force of gravity. Students review their understanding of gravity and how to linearize a set of data. Students use a gravity simulation to collect data on what variables change the force of gravity and how they are related to the force of gravity. Students apply Newton's Law of Gravitation to calculate values to predict the force of gravity, and students use plotted data to calculate the value of the gravitational constant.

Snapshot

Engage

Students recall their prior knowledge about the force of gravity. Then students review how to linearize a set of data.

Explore

Students manipulate variables to determine how the force of gravity is affected by each independent variable. They use the relationships they find to develop Newton's Law of Gravitation.

Explain

Students apply the universal law of gravity to calculate force, distance, or mass involved.

Extend

Students examine how the gravitational constant was originally calculated with a torsional pendulum. Students then use a set of data to calculate the gravitational constant and calculate the percent error to the accepted value.

Evaluate

Students demonstrate their understanding of the relationship between the variables that affect gravity through a conceptual question. Students demonstrate their understanding of the quantitative relationship by applying Newton's Law of Gravitation.

Standards

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-PS2: Motion and Stability: Forces and Interactions
HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Attachments

- Exit Ticket Teacher Guide - More Attractive Than You Think.docx
- Exit Ticket Teacher Guide - More Attractive Than You Think.pdf
- Finding the Gravitational Constant Teacher Guide - More Attractive Than You Think.docx
- Finding the Gravitational Constant Teacher Guide - More Attractive Than You Think.pdf
- Finding the Gravitational Constant—More Attractive Than You Think - Spanish.docx
- Finding the Gravitational Constant—More Attractive Than You Think - Spanish.pdf
- Finding the Gravitational Constant—More Attractive Than You Think.docx
- Finding the Gravitational Constant—More Attractive Than You Think.pdf
- Gravity Simulation—More Attractive Than You Think - Spanish.docx
- Gravity Simulation—More Attractive Than You Think - Spanish.pdf
- Gravity Simulation—More Attractive Than You Think.docx
- Gravity Simulation—More Attractive Than You Think.pdf
- Lesson Slides - More Attractive Than You Think.pptx
- Newton's Law of Gravitation Teacher Guide - More Attractive Than You Think.docx
- Newton's Law of Gravitation Teacher Guide - More Attractive Than You Think.pdf
- Newton's Law of Gravitation—More Attractive Than You Think - Spanish.docx
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- Newton's Law of Gravitation—More Attractive Than You Think.pdf
- Relationship Between Graphs Card Sort—More Attractive Than You Think - Spanish.docx
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- Relationships Between Graphs Card Sort Teacher Guide - More Attractive Than You Think.pdf

Materials

- Lesson Slides (attached)
- Relationship Between Graphs Card Sort (attached, 1 per group of 3-4 students)
- Relationships Between Graphs Teacher Guide (attached)
- Gravity Simulation handout (attached, 1 per student)
- Gravity Simulation Teacher Guide
- Newton’s Law of Gravitation handout (attached, 1 per student)
- Newton’s Law of Gravitation Teacher Guide
- Finding the Gravitational Constant handout (attached, 1 per student)
- Exit Ticket Solution Key (attached)
- Class set of calculators
- Student devices with internet access
- Sticky notes (1 per group of 2-3 students)
- Notebook paper
- Pencils

25 minutes

Engage

Teacher's Note: Lesson Preparation

In advance of teaching the lesson, print the attached **Relationship Between Graphs Card Sort**. Print enough copies so that there are enough for students to work in groups of three to four. Cut out the cards prior to the lesson or have students cut them out before sorting. Consider laminating and saving the cards for future use.

Use the attached **Lesson Slides** to guide the lesson. Display **slides 1-4** to introduce the essential questions and learning objectives with students. Move to **slide 5** and introduce the Justified True or False instructional strategy to students. Break students into groups of three to four and give groups two to three minutes per slide to evaluate each of the statements on **slides 6-8**. After each slide, pick a few groups to share their response and ask the rest of the class whether they disagreed or had used any other supporting evidence.

Teacher's Note: Possible Student Responses

1. False - Objects that have more mass have a larger weight (force of gravity). Scales will read different weights for different objects.
2. False - If you go to a different planet or even to a different altitude on the earth, then the acceleration of gravity changes. This question ignores the effects of air resistance since it specifically references the effect of gravity alone.
3. False - The acceleration of the object is due to the net force on the object, which changes when the elevator accelerates. However, the acceleration of gravity is only dependent on the force of gravity divided by the mass of the object.

Display **slide 9** and use the Card Matching instructional strategy to help students review the relationships between graphs and equations. Place students into groups of three to four and pass out the Relationships Between Graphs Card Sort cards. Provide about ten minutes for students to match the descriptions to the graphs. Assign each group one graph to write the original relationship between x and y on the board, on a piece of butcher paper, or in a google document to display to the class. Overlapping groups can verify that they agree with what is written.

Display **slide 10** and have the groups spend three to four minutes discussing the question before asking the class to respond. Once students have answered correctly, display **slide 11** and review the two steps to make the linear graph. See the attached **Relationships Between Graphs Teacher Guide** for a solution to the card sort.

30 minutes

Explore

Display **slide 12** and pass out the attached **Gravity Simulation** handout. Direct students to use their personal devices and access the online Phet simulation at the following link: https://phet.colorado.edu/en/simulations/gravity-force-lab.

Have students work in pairs to complete the online simulation and handout. Students should keep their handout for the Explain section of the lesson. More specific information is provided in the attached **Gravity Simulation Teacher Guide**.

Display **slide 13** and have students use the Sticky Bars instructional strategy to build consensus on question 7 from the Gravity Simulation handout. Have students write down their equation on a sticky note and then have the first group stick their notes on the wall. The following groups either put their notes directly above the first group's sticky note if it is the same equation or create a new column if it is a different equation. Once all of the groups are on the wall, have a quick class discussion to arrive at consensus about evidence for which one is the right equation.

Consider stopping at this point for the day.

50 minutes

Explain

Display **slide 14** and pass out the attached **Newton's Law of Gravitation** handout. Use a modified version of the Pass the Problem instructional strategy to have the students work through the problems. First, break the class into six groups for the 6 problems on the handout. Assign each group a problem from the handout. Next break each of these groups into pairs. Provide about five to six minutes for students to record a response to their assigned question.

Collect all students' responses and sort them by question number; then display **slide 15**. Provide students with a set of responses based on the following order:

- Problem 1 students look over problem 2.
- Problem 2 students look over problem 3.
- Problem 3 students look over problem 4.
- Problem 4 students look over problem 5.
- Problem 5 students look over problem 6.
- Problem 6 students look over problem 1.

Give the combined groups 10-12 minutes to read over the responses and develop a consensus about how to get to the correct answer. Tell each group to elect one person to present the question and the solution, while the rest of the class takes notes over the solutions on their handout.

Consider stopping at this point for the day.

Teacher's Note: Student Responses

Example responses are provided in the attached **Newton's Law of Gravitation Teacher Guide**.

The order of the questions was chosen to give every group of students one conceptual and one quantitative problem to solve between the problem they initially solve and the problem that they come to a consensus about.

40 minutes

Extend

Pass out the attached **Finding the Gravitational Constant** handout and display **slide 16** to go over the I Notice / I Wonder instructional strategy. Display **slide 17** and **slide 18** and show the video on each slide to have the students fill out the I Notice / I Wonder table on the handout.

Use the modified Think-Pair-Share instructional strategy to have the students go over the process individually, in pairs, and as a class. Display **slide 19** and have the students individually write notes over the process to determine the value of the gravitational constant. Display **slide 20** and in pairs, have the students write notes over the process to determine the value of the gravitational constant. Display **slide 21** and have a class discussion over the answers to reiterate what needs to be done.

Display **slide 22** and have the students finish the remainder of the Finding the Gravitational Constant handout and turn it in.

Teacher's Note: Choices in Finding the Gravitational Constant

Be careful to make sure that students understand that they could decide to include the constants or not include the constants in their graph. In the discussion bring up different examples of what could be graphed to solve for G.

15 minutes

Evaluate

Display **slide 23** and **slide 24**. Have students individually answer the two questions on notebook paper and turn it in before leaving the classroom for the day. Review students' papers to assess understanding of the lesson content. See the attached **Exit Ticket Solution Key** for answers to the questions.

Resources

- Aasoka. (n.d.). Determining gravitational constant. https://www.youtube.com/watch?v=4wt0135G8kM&t=38s
- *Gravity Force Lab*. PhET. (n.d.). https://phet.colorado.edu/en/simulations/gravity-force-lab
- K20 Center. (n.d.). Justified True or False. Strategies. https://learn.k20center.ou.edu/strategy/174
- K20 Center. (n.d.). Card Matching. Strategies. https://learn.k20center.ou.edu/strategy/1837
- K20 Center. (n.d.). Sticky Bars. Strategies. https://learn.k20center.ou.edu/strategy/129
- K20 Center. (n.d.). Pass The Problem. Strategies. https://learn.k20center.ou.edu/strategy/151
- K20 Center. (n.d.). I Notice / I Wonder. Strategies. https://learn.k20center.ou.edu/strategy/180
- K20 Center. (n.d.). Think-Pair-Share. Strategies. https://learn.k20center.ou.edu/strategy/139