Deriving Newton's Law of Gravitation

Watch the Video Here

Pages 1-4 Deriving Newton's Law of Gravitation
NGSS & CASEL lesson

Materials Required for This Lesson/Activity	
Quantity	**Description**
1 per student	Computer with Internet Access
3 Feet per group	Masking Tape
3 pieces per group	Printer Paper
Class Set	Text Books

Deriving Newton's Law of Gravitation

Grade/ Grade Band 9-12	**Topic:** Newton's Law of Gravitation

Brief Lesson Description: Students will utilize a computer simulation in order to model a relationship between the mass of two objects and the distance between them. They will compare their relationship with Newton's Law of Gravitation.

Performance Expectation(s):
NGSS 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.

Specific Learning Outcomes:
Students will be able to:
-Use a computer simulation to generate qualitative and quantitative observations about the relationship between gravity, the mass of two objects, and the distance between two objects.
-Students will create a mathematical representation (equation or graph) to describe this relationship.
-Use the mathematical representation to predict the gravitational force between two objects.
-Compare the mathematical representation to Newton's Law of Gravitation.

Narrative / Background Information

Prior Student Knowledge:
-Students should have an understanding of proportional relationships.
-Students should be able to use a graph and/or data table to create an equation.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomenon to describe explanations.	**PS2.B: Types of Interactions** ● Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. ● Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space.	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4)

Possible Preconceptions/Misconceptions:
Common misconceptions include:
-Gravitational fields are dependent on movement of objects.
-The amount of gravity is related to the size of a planet's atmosphere.
-Gravity is stronger between distant objects.
-Gravity only acts between large forces close to one another.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Start the lesson by displaying a picture of a space capsule returning to Earth through the atmosphere. (Link to example image)
Use the Notice and Wonder strategy for students to observe the image. ***Have students share as a class their notices (observations) about the image and their wonders (questions) generated by the picture.***

Next, show the students the X-STEM Video "Ensuring a Safe Return from Space." After watching the video, return the image of the space capsule to the screen and ask them how this connects to Captain Seik's work with the Air Force.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:
Explain to students that Captain Seik's work depends on using mathematical and computational representations of the phenomenon of objects returning to Earth to determine if a spacecraft/satellite will safely return to Earth from Space. Explain that today we will be using a computer model to create our own mathematical representation of a phenomenon.

Students will need a computer with internet access to complete the next portion of this lesson.

Have students log in to https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_all.html

Provide students time to explore the simulation. After this exploration, have students discuss the following questions:

1. ***What variables can you adjust/manipulate in this model?*** (Mass of Object 1, Mass of Object 2, Distance Between Object 1 and Object 2)
2. ***What do you notice about how the force of gravity changes when you increase the mass of objects? decrease the mass of objects?*** (As mass increases, gravity increases. As mass decreases, gravity decreases)
3. ***What do you notice about how the force of gravity changes when you increase the distance between the objects? decrease the distance between objects?*** (As the distance between the objects increases, the gravity decreases. As the distance between the objects decreases, the gravity increases).
4. ***When we discuss gravity, we often talk about objects falling or moving in an orbit. In this model, is this observed? Why do you think this might be?*** (Gravity is not dependent on motion, but can be observed by objects that are being attracted between each other which causes motion).
5. ***Do you think there is a mathematical relationship between the mass of the blue object and the red object?*** *There is a mathematical relationship. As one object's mass changes, the other object changes in a similar manner. For example, if I double the mass of one object, the gravitational force doubles.*

Now explain to students that they are going to collect and graph data. Break the class into two groups.

Have group one collect 10 data points for the following question and then create a graph of the data:
How does increasing the mass of object 1 (red) affect the gravitational force? (Assume a constant distance)

Have group two collect 10 data points for the following question and then create a graph of the data:
How does increasing the distance between the objects affect the gravitational force? (Assume the mass of the objects is constant)

Next, pair students from group 1 with group 2. Have them discuss the following questions:

1. ***What is the relationship between mass and force of gravity?***
2. ***What would happen to the force of gravity if you doubled the mass of object one? halved the mass of object one?***
3. ***Write an equation to describe this relationship using Mass 1 (M_1), Mass 2 (M_2), and Force of Gravity (F_g)?***
4. ***What is the relationship between distance and the force of gravity?***
5. ***What would happen to the force of gravity if you doubled the distance between the objects? halved the distance between the objects?***
6. ***Write an equation to describe this relationship using Distance (r) and Force of Gravity (F_g)?***
7. ***Combine your two equations into one relationship.***

Discuss as a class the equations that partners have created to represent this system. Compare and contrast their ideas and how they came to their representations.

EXPLAIN: Concepts Explained and Vocabulary Defined:

Students will now learn about Newton's Universal Law of Gravitation. Students have two different ways to do this.

Option 1:
Have students read the text and take notes about this law. After reading the text, have students complete the comprehension questions at the end of the reading.

Option 2:
Show students the video and take notes about this law. After watching the video, have them write a summary explaining the law and what each of the variables means.

Vocabulary:
Gravity: the force that attracts a body toward the center of the earth, or toward any other physical body having mass.

ELABORATE: Applications and Extensions*:*

Have students compare the law of gravitation with the equations they created in the Engage section of this lesson. How are they similar? How are they different?

Next, have students complete the practice problems found here or here.

EVALUATE:
Formative Assessment:
Prompts found throughout the lesson are found in ***bold italics***.

Summative Assessment:
Have students demonstrate their understanding of the mathematical representation using the derived/provided equation.

Elaborate Further / Reflect: Enrichment:
Provide students an opportunity to learn about the relationship between gravity and human physiology by reading the article "All about G-Forces" or explore how their own gravitational force (weight) changes on planets using the simulation here.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency: Relationship Skills

In the video, Captain Seik discussed the importance of collaboration in his work. Today, we are going to explore this idea in our classroom.

Start the lesson by having students use the Simultaneous Round Table strategy to generate a list of the qualities of a good teammate. After each team has created a list, share as a whole class to come up with a class list.

Ask students to discuss which of these qualities they think is most important. Have them support their answer with clear reasoning.

Then provide students with the following challenge in their table groups:
Your task as a group is to create a structure that meets the following requirements collaboratively:
-Uses 3 or fewer pieces of paper
-Uses 3 feet or less of masking tape
-Build a structure to hold as many textbooks as possible
-Must be > 1" off the table
-Must be free standing

Provide students 10 minutes to complete the challenge.

As a class, discuss the following prompts:

1) Were you successful? How do you know?
2) What strategies did you use as a team to complete this task?
3) Can you do better?-->Challenge them to pick 2 traits to work on and do better!

Provide students an additional 10 minutes to complete the challenge.

As a class, discuss the following prompts:

1) How many teams improved? Why was this?
2) How did focusing on specific collaboration traits help your team?
3) What qualities do you think are most important now? How did this change? Why?

INTERDISCIPLINARY CONNECTIONS/IDEAS

Mathematics: Explore mathematical representations of other space phenomena using the NASA Space Math Booklets found here.

Computer Science: Use Scratch to create mathematical models of various phenomena. Find out more here.

World History: Have students explore and learn about how Issac Newton is the father of both Calculus and Physics. Example lesson plan found here.

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