Name: _____   Date: _____

Student Exploration: Gravitational Force

Vocabulary: force, gravity, vector

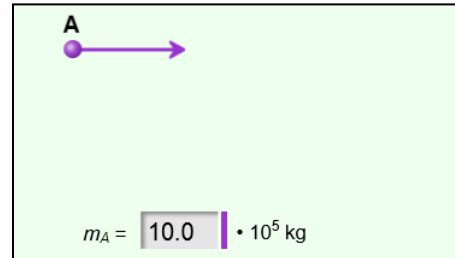**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)
On the night of a Full Moon, Mary decides to do an experiment with **gravity**. At midnight, she climbs into her backyard tree house, leans out the window, and holds an acorn as high as she can. She lets go and is disappointed to see the acorn plummet back down to Earth.

1. Why did the acorn fall to Earth instead of rising up to the Moon? _____

    _____

2. Give two reasons why we feel Earth's gravity more strongly than the Moon's gravity.

    _____

    _____

Gizmo Warm-up
From acorns to apples, gravity causes nearly any object to fall to Earth's surface. Gravity also causes the Moon to orbit Earth and Earth and the other planets to orbit the Sun. The *Gravitational Force* Gizmo allows you to explore the factors that influence the strength of gravitational force.
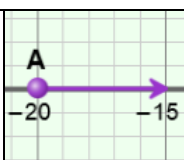

To begin, turn on the **Show force vector** checkboxes for objects A and B. The arrows coming from each object are **vectors** that represent gravitational **force**. The length of each vector is proportional to the force on each object.

1. Move object **A** around. As object **A** is moved, what do you notice about the direction of the

    two force vectors? _____

2. How do the lengths of the two vectors compare? _____

3. Drag object **A** closer to object **B**. How does this change the gravitational force between the

    two objects? _____

Activity A: Gravity and mass	Get the Gizmo ready: • Turn on **Show vector notation** for each object. • Check that each object's mass (m_A and m_B) is set to $10.0 \cdot 10^5$ kg.	

Question: How does mass affect the strength of gravitational force?

1. Form hypothesis: How do you think the masses of objects **A** and **B** will affect the strength of

   the gravitational force between them? _____

   _____

2. Predict: How do you think the gravitational force between two objects will change if the mass

   of each object is doubled? _____

3. Measure: Turn on **Show grid**. Place object **A** on the **x** axis at -20 and object **B** on the **x** axis at 20. The force on object **A** is now $0.0417\mathbf{i} + 0\mathbf{j}$ N. That means that the force is 0.0417 newtons in the x direction (east) and 0.0 newtons in the y direction (north).

   A. What is the magnitude of the force on object **A**? $|F_A|$ = _____

   B. What is the magnitude of the force on object **B**? $|F_B|$ = _____

4. Gather data: You can change the mass of each object by clicking in the text boxes. For each mass combination listed in the table below, write magnitude of the force on object A. Leave the last two columns of the table blank for now.

m_A (kg)	m_B (kg)	$|F_A|$ (N)	Force factor	$m_A \cdot m_B$ (kg²)
$10.0 \cdot 10^5$ kg	$10.0 \cdot 10^5$ kg			
$10.0 \cdot 10^5$ kg	$20.0 \cdot 10^5$ kg			
$20.0 \cdot 10^5$ kg	$20.0 \cdot 10^5$ kg			
$20.0 \cdot 10^5$ kg	$30.0 \cdot 10^5$ kg			

5. Calculate: To determine how much the force is multiplied, divide each force by the first value, 0.0417 N. Round each value the nearest whole number and record in the "Force factor" column.

   Next, calculate the product of each pair of masses. Fill in these values in the last column. Compare these numbers to the "Force factor" numbers.

(Activity A continued on next page)

Activity A (continued from previous page)

6. <u>Analyze</u>: How much does the force increase if each mass is doubled? _____

_____

7. <u>Analyze</u>: How do the force factors compare to the products of the masses? _____

_____

_____

8. <u>Apply</u>: What would you expect the force to be if the mass of object **A** was $50.0 \cdot 10^5$ kg and

   the mass of object **B** was $40.0 \cdot 10^5$ kg? _____
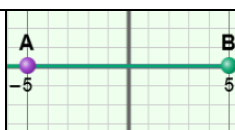
   Check your answer with the Gizmo.

9. <u>Draw conclusions</u>: How do the masses of objects affect the strength of gravitational force?

   _____

   _____

   _____

10. <u>Summarize</u>: Fill in the blank: The gravitational force between two objects is proportional to

    the _____ of the masses of the objects.

11. <u>Apply</u>: Suppose an elephant has a mass of 1,800 kg and a person has a mass of 75 kg. If
    the strength of gravitational force on the person was 735 N, what would be the gravitational
    force on the elephant? (Assume both the person and elephant are on Earth's surface.)

    _____

    Show your work:

Activity B: **Gravity and distance**	Get the Gizmo ready: • Turn on **Show distance**. • Set m_A and m_B to 10.0 • 10^5 kg.	

Question: How does distance affect the strength of gravitational force?

1. <u>Form hypothesis</u>: How do you think the distance between objects **A** and **B** will affect the

   strength of the gravitational force between them? _____

   _____

2. <u>Predict</u>: How do you think the gravitational force between two objects will change if the

   distance between the objects is doubled? _____

3. <u>Measure</u>: Place object **A** on the **x** axis at -5 and object **B** on the **x** axis at 5.

   A. What is the distance between the two objects? _____

   B. What is the magnitude of the force on object **A**? $|F_A|$ = _____

4. <u>Gather data</u>: For each set of locations listed below, record the distance and the force on object **A**. Leave the last two columns blank for now.

Object A	Object B	Distance (m)	$\|F_A\|$ (N)	Force factor	$\dfrac{1}{Distance^2}$
(-5, 0)	(5, 0)				
(-10, 0)	(10, 0)				
(-15, 0)	(15, 0)				
(-20, 0)	(20, 0)				

5. <u>Interpret</u>: How does increasing the distance affect the force? _____

   _____

6. <u>Calculate</u>: To calculate the force factor, divide each force by the original force (0.667 N). Write each force factor with three significant digits. Next, calculate the reciprocal of the square of each distance and fill in the last column of the table. Write each of these values with three significant digits as well. (The unit of 1/$distance^2$ is square meters, or m^2.)

(Activity B continued on next page)

Activity B (continued from previous page)

7. <u>Analyze</u>: Compare the force factors to the 1/*distance*^{2} values in your table. What is the relationship between these values?

_____

_____

8. <u>Apply</u>: What would you expect the force to be if the distance was 50 meters? _____

   Use the Gizmo to check your answer.

9. <u>Make a rule</u>: Based on the measured force between objects that are 10 meters apart, how can you find the force between objects that are any distance apart?

_____

_____

10. <u>Summarize</u>: Fill in the blanks: The gravitational force between two objects is proportional to

    the _____ of the distance _____

11. <u>Challenge</u>: In activity A, you found that the gravitational force between two objects is proportional to the product of their masses. Combine that with what you have learned in this activity to complete the universal formula for the force of gravity below. (Hint: In the equation, *G* is a constant.) Check your answer with your teacher.

$$F_{Gravity} = G \frac{\Box \cdot \Box}{\Box}$$

12. <u>On your own</u>: Use the Gizmo to find the value of *G* in the formula above. List the value and describe how you found it below. The units of *G* are newton · meter^2 ÷ kilograms^2, or N·m^2/kg^2. Check your answer with your teacher.

    G = _____

    Show your work: