Gravity by Numbers

Model how mass and distance change gravitational force.

P.5.b "Develop and use a model to describe the mathematical relationship between mass, distance, and force as expressed by Newton's law of universal gravitation."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline the equation, circle the symbols for the two masses and center-to-center distance, and number the two sentences that explain how changing mass or distance changes force.

A Probe Near a Planet

1. Imagine a probe drifting past a distant planet. Gravity pulls the probe toward the planet, even without contact. To model that pull, treat both objects as points at their centers. Let M be planet mass, m probe mass, and r the distance between their centers. The force's size is $F = GMm/r^2$, where G is a constant.

2. A model predicts changes by comparing two cases while keeping the other quantities fixed. Multiplying either mass by a factor multiplies force by that factor. Multiplying center-to-center distance by a factor divides force by the square of that factor. These rules apply to the force's size; each object feels a pull of the same size in opposite directions.

3. The table compares five imagined probe encounters. Every number is measured relative to case A: a mass of 2 means twice its mass in A, and a distance of 2 means twice the center-to-center distance. Force values follow the equation, not a change in the constant G. Use the rows to test how several changes can act together.

PROBE ENCOUNTERS, RELATIVE TO CASE A

Case	Planet mass	Probe mass	Center distance	Force
A	1	1	1	1
B	2	1	1	2
C	1	2	1	2
D	1	1	2	1/4
E	2	2	2	1

2 ANSWER WITH EVIDENCE

Use the passage

1. Compare cases A and B. Which model quantity changes, and how does that change the force?

2. Compare cases A and D. Use the distance term in the equation to explain D's force.

3. In case E, both masses and the center distance are twice their values in A. Why is the force still 1?

4. Suppose the probe mass and center distance are each three times their values in A, while planet mass stays the same. What is the force in A units? Show the factors you used.

3 YOUR TURN

Your own words

Design two new probe encounters that differ from cases A through E. For each, state the planet mass, probe mass, and center distance in A units, calculate the force in A units, and explain how your model accounts for the difference between the two forces.

Gravity by Numbers

PART 1 · READ AND MARK

Underline the equation, circle the symbols for the two masses and center-to-center distance, and number the two sentences that explain how changing mass or distance changes force. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	Compare cases A and B. Which model quantity changes, and how does that change the force?	**Planet mass doubles while probe mass and distance stay fixed, so force doubles.**
2	Compare cases A and D. Use the distance term in the equation to explain D's force.	**Center distance doubles. Because distance is squared in the denominator, force becomes 1/4 as large.**
3	In case E, both masses and the center distance are twice their values in A. Why is the force still 1?	**Doubling both masses multiplies force by 4, while doubling distance divides it by 4. The changes cancel.**
4	Suppose the probe mass and center distance are each three times their values in A, while planet mass stays the same. What is the force in A units? Show the factors you used.	**The force is 1/3 in A units: $3/(3^2) = 3/9 = 1/3$.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

In encounter X, planet mass is 3, probe mass is 1, and center distance is 1, so force is $(3 \times 1)/1^2 = 3$ in A units. In encounter Y, planet mass is 3, probe mass is 2, and center distance is 3, so force is $(3 \times 2)/3^2 = 2/3$ in A units. Y has twice X's probe mass, but its distance is three times as large, reducing its force to 2/9 of X's force.

Accept any two encounters distinct from A through E if their forces follow the mass product divided by the square of center distance. The comparison should account for all quantities that change.