Orbits in Motion

Build a model that connects orbital patterns to gravity.

ESS.1B.3 "Design a model (e.g., a gravity simulation using PVC and a neoprene screen) to demonstrate Kepler's laws and the relationships of the orbits of objects in our solar system..."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline each pattern the projector shows, circle the settings that make the model run, and number the model's limitation. Use your marks to connect what the objects do with what causes their motion.

A Comet on the Museum Floor

1. At a science museum, a digital projector draws a comet's path around the Sun on the floor. The operator places the Sun at one focus of an ellipse, not at its center. She marks the comet's position every ten days. Near the Sun, the marks spread farther apart because the comet moves faster. Far away, the marks crowd together because it moves slower. Lines from the Sun to the comet sweep out regions between each pair of marks. Although the regions have different shapes, each has the same area for its ten-day interval. This is Kepler's equal-areas law in action.

2. The operator adds two imaginary planets, each moving in a nearly circular orbit around the same Sun. One travels farther from the Sun than the other. Both paths are ellipses, with circles as a special case, so each follows Kepler's first law. The outer planet takes longer to complete one trip and has a lower average orbital speed. Kepler's third law gives a sharper prediction: for objects orbiting the same central body, orbital period squared is proportional to the orbit's semimajor axis cubed. If one orbit's semimajor axis doubles, its period grows by a factor of about 2.8.

3. To build the projection, the operator enters the Sun's mass and gives each object a starting position and sideways velocity. Newton's law of gravitation makes the pull stronger for greater masses and weaker as distance increases, following an inverse-square rule. Newton's first law predicts straight-line motion without a net force. Gravity changes the object's velocity by causing acceleration, as described by his second law. The model calculates each new position from this changing motion rather than forcing an ellipse onto the screen. It ignores other planets' pulls, so a real comet's orbit may drift from the projected path.

2 ANSWER WITH EVIDENCE

Use the passage

1. How could you use the comet's ten-day marks to test Kepler's equal-areas law? Explain why the marks are farther apart near the Sun.

2. In the model, one planet has twice the semimajor axis of another planet orbiting the same Sun. How should their orbital periods compare?

3. Why does the comet turn instead of continuing in a straight line? Connect your answer to Newton's laws.

4. Why might a real comet slowly move away from the model's projected path, even if the starting position and velocity are correct?

3 YOUR TURN

Your own words

Design a digital model of two moons orbiting a fictional planet, with one oval orbit and a second orbit with twice its semimajor axis. In one paragraph, describe what you would set and display to test all three of Kepler's laws, explain how Newton's laws drive the motion, and name one limit of your model.

ANSWER KEY

Orbits in Motion

HIGH SCHOOL · ESS.1B.3

PART 1 · READ AND MARK

Underline each pattern the projector shows, circle the settings that make the model run, and number the model's limitation. Use your marks to connect what the objects do with what causes their motion. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	How could you use the comet's ten-day marks to test Kepler's equal-areas law? Explain why the marks are farther apart near the Sun.	**Compare the areas swept out from the Sun between each pair of ten-day marks. They should be equal, even though the marks are farther apart near the Sun because the comet moves faster there.**
2	In the model, one planet has twice the semimajor axis of another planet orbiting the same Sun. How should their orbital periods compare?	**The planet with twice the semimajor axis should take about 2.8 times as long to complete an orbit.**
3	Why does the comet turn instead of continuing in a straight line? Connect your answer to Newton's laws.	**Without a net force, it would continue in a straight line. The Sun's gravitational pull causes acceleration that continually changes the comet's velocity.**
4	Why might a real comet slowly move away from the model's projected path, even if the starting position and velocity are correct?	**The model ignores other planets' gravitational pulls, which can change the real comet's motion.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I would enter the planet's mass and each moon's starting position and sideways velocity, then calculate their paths. I would display the planet at a focus of each oval path. Clock marks and shaded areas swept out in equal time intervals would let me compare each moon's motion near and far from the planet. A period counter would test whether the wider orbit takes about 2.8 times as long. Without gravity, Newton's first law predicts straight paths. The planet's gravitational pull instead accelerates the moons and changes their velocities. My model would ignore the moons' pulls on each other.

Accept models that show the planet at an orbital focus, equal areas in equal times, and a period about 2.8 times longer when the semimajor axis doubles. The response should connect gravity to changing velocity and identify a plausible model limitation.