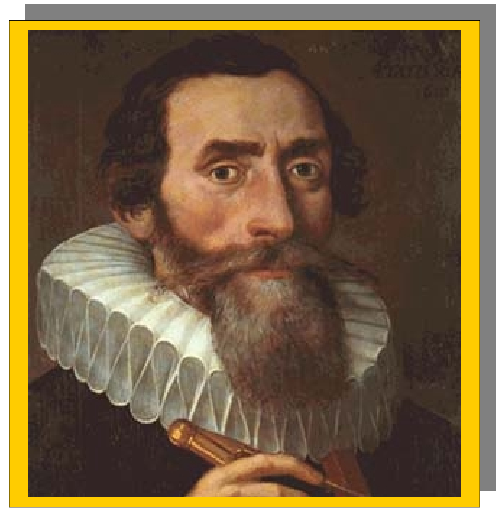
GENESIS
SEARCH FOR ORIGINS
Education

Destination L1:
A Thematic Unit

Kepler's Laws of Planetary Motion

TEACHER GUIDE



Johannes Kepler (1546-1630) used Tycho Brahes data to determine the laws of planetary motion.

BACKGROUND INFORMATION

The science activities in this module deal with the concept of travel as it relates to natural objects (planets) traveling around the sun. The activities are designed to let the students discover Kepler's Laws of Planetary Motion. In "The Inclined Pendulum," students use a simulation to model the fact that a decrease in gravity causes a decrease in orbital velocity, and that more distant planets revolve around the sun at slower velocities (Kepler's third law). The students conclude by reading the Student Text, "L1 or Bust," in which they learn about the LaGrange Points and study the trajectory that is used by the Genesis spacecraft during its trip to orbit L1 and back to Earth.

The National Science Education Standards call for teachers to guide and facilitate learning. The activities in this section allow students to discover how the planets travel around the sun in orbits. As teachers carefully observe their students during these activities, it is important to decide how and when to guide the class based on how students are proceeding in their learning.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

Science as Inquiry
- Understandings about scientific inquiry

Physical Science
- Motions and forces

Earth and Space Science
- Earth in the solar system

History and Nature of Science
- History of science

Grades 9-12

Science as Inquiry
- Understandings about scientific inquiry

Physical Science
- Motions and forces

History and Nature of Science
- Historical perspectives

(View a full text of the National Science Education Standards.)

PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS

Grades 6-8

Numbers and Operations

Understand numbers, ways of representing numbers, relationships among numbers and number systems.

Understand meanings of operations and how they relate to one another.
Compute fluently and make reasonable estimates.

Algebra
Use mathematical models to represent and understand quantitative relationships.

Geometry
Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
Use visualization, spatial reasoning, and geometric modeling to solve problems .

Problem Solving
Solve problems that arise in mathematics and in other contexts.

Connections
Recognize and apply mathematics in contexts outside of mathematics.

(View a full text of the Principles and Standards for School Mathematics.)

NATIONAL TECHNOLOGY EDUCATION STANDARDS ADDRESSED

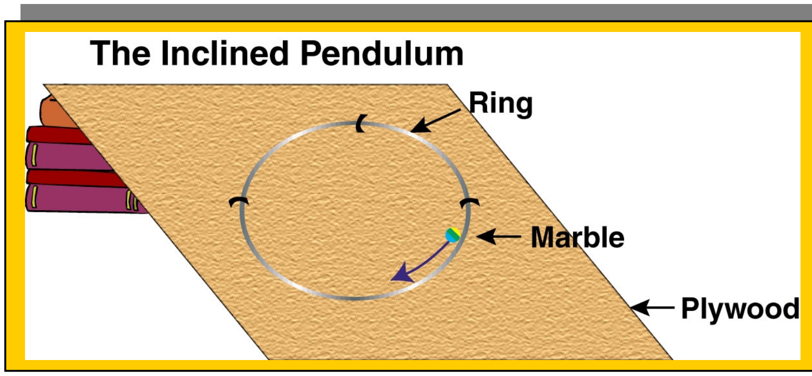
K-12

Technology productivity tools
Students use technology tools to enhance learning, increase productivity, and promote creativity.

Technology problem-solving and decision-making tools
Students employ technology in the development of strategies for solving problems in the real world.

(View a full text of the National Technology Education Standards.)

MATERIALS



"The Inclined Pendulum"

For each group of four students:

- Metal ring mounted onto a piece of plywood
- Marble
- Student Activity "The Inclined Pendulum"
- Stopwatch or other timing device
- Five textbooks (all about the same size)

PROCEDURE

"The Inclined Pendulum"

Alternate Strategy Tip

This activity can be completed as a class demonstration with the students collecting the data from one apparatus.

1. There is some advance preparation for this activity. The teacher should obtain enough plywood and metal rings for each student group. The rings can be mounted on the plywood with a couple of industrial staples or heavy-duty tape.

2. Before distributing the student activity, demonstrate how the inclined pendulum can be used to model a decrease in gravity. Set the apparatus onto a book and demonstrate how to roll the marble. Place the marble on the inside of the ring and release. Students should practice counting the number of times the marble swings in 10 seconds. Repeat this several times so the students determine the best way to count swings. One way might be to count the number of times it passes by a mark on the wood by the bottom of the ring. Emphasize how it is important for the students to release the marble from the same point for each trial. Explain to students that after completing three trials for one book, they should add a second book under the apparatus and repeat. Tell students that this simulates an increase in gravity.

3. Distribute the Student Activity "The Inclined Pendulum." Students should follow the procedure, fill in the data table, and make a graph showing their results.

4. Suggested answers for student procedures 8-9.
   - Based on your results, how does the amount of gravity affect the velocity of the marble? (Students may state that the more books that are used, the more swings the marble makes in 10 seconds. Therefore, an increase in the gravity results in faster marbles.)
   - In what ways does this compare with planets orbiting the sun? (According to Newton's Law of Gravitation, masses at greater separations have less gravitational force than those closer together. Therefore, planets that are farther from the sun have more gravity than those that are closer.) (According to Newton's Law of Gravitation, masses at greater separations have less gravitational force than those closer together. Therefore planets that are farther from the sun have less gravity than those that are closer.)

5. Questions 10 and 11 on the student activity refer to the table of mean orbital velocities. Students should make the connection that more distant planets travel around the sun more slowly than those that are closer to the sun. Suggested answers for procedures 10-11 are below.
   - Based on the mean orbital velocity and the mean distance from the sun, describe the relationship between the distance from the sun and the orbital velocity. (Students should suggest that based on this data table, the farther the planet is from the sun, the slower its orbital velocity.)
   - Describe Kepler's Third Law of Planetary Motion in your own words. (Answers will vary, but students should suggest that the more distance from the planet to the sun, the slower the planet moves.)

Teaching Tip

Students may not know the definition of an astronomical unit (AU). Encourage interested students to use the Genesis glossary to find the definition.

6. Once students have completed each of the activities, distribute the Student Text, "L1 or Bust!" to each student. This text reviews the concepts from the activities in this teacher guide and challenges students to interpret the Genesis launch trajectory graphic. Answers for these questions are below.
   - At what distance did the Genesis spacecraft cross the moon's orbit? (Just under 0.5 million kilometers)
   - How long does it take for the Genesis spacecraft to arrive at L1? (2.7 months)
   - How many orbits does the Genesis spacecraft make around L1? (5)
   - What is the approximate diameter of each of these orbits? (1.5 million kilometers)
   - How many months does each orbit take? (29.3 months divided by 5 orbits = 5.86 months)
   - Describe the Genesis spacecraft's trip back to the Earth. (Answers will vary. Some students may suggest that the spacecraft travels back to the Earth, just beyond the moon's orbit, and then goes to L2 to reposition itself for a daylight reentry.)
   - Why will the Genesis spacecraft travel around L2? (It does this so that it can achieve a daylight reentry. You may want to add that this is because of the helicopter capture.)
   - What year will the Genesis spacecraft return to the Earth? (2004)
   - How many years will the Genesis spacecraft spend in space? (37.3 months divided by12 months per year = 3.11 years)
   - Why is the sun not shown in this graphic? (Students may suggest that the sun does not fit into this scale.) (It would be another 92 million miles away from the L1 point.)
   - Write a paragraph describing the trajectory of the Genesis spacecraft. (Answers will vary, but students should indicate the outward leg, the five halo orbits, and the return and recovery aspects of the trajectory.)

7. Once the students have completed all of the activities and texts on Kepler's laws, ask them to take out their journals and look at some of the questions they wrote down at the beginning of this unit. Ask them to write answers based on information they learned in this unit. Next, ask students to record a summary of what they learned in their journals. Finally, ask them to write additional questions they have as a result of activities in this unit. Hold a class discussion on how they might go about finding answers to questions that they still have about planets' orbits.

URLs

http://csep10.phys.utk.edu/astr161/lect/history/kepler.html
Kepler's Laws of Planetary Motion

http://csep10.phys.utk.edu/astr161/lect/solarsys/revolution.html
Revolution and rotation of the planets

http://map.gsfc.nasa.gov/m_mm/ob_techorbit1.html
Goddard Space Flight Center MAP education outreach program re: Lagrange points

http://solarsystem.nasa.gov/features/planets/planet_profiles.html
Profiles of the planets

http://www.kepler.arc.nasa.gov/johannes.html
Kepler biography

http://www.nasaexplores.com/lessons/01-079/
What is orbit?