COMET

A Teacher's Activity Guide

Another in the Series of
Challenger Learning Adventures
from

Challenger CENTER

Cometary Orbits

Background

Johannes Kepler, who was born in 1571, was an astronomer who struggled to find a mathematical way to describe how the planets moved around the Sun. For many years, astronomers believed that the planets moved in perfect circles. However, Kepler eventually realized that this wasn't the case. In 1609 he stated his first of three laws of planetary motion. It said, "The orbit of each planet is an ellipse, with the Sun located at one focus."

An ellipse is a geometrical shape that looks much like a stretched out circle. To draw one, it is easiest to drape a loop of string around two tacks that are placed in a piece of paper. With a pencil, draw a curve by pulling the string taught and sweeping it around the paper. [See diagram on p. 10] The place where the two tacks are located are called the ellipse's foci (plural of focus). The length of the long axis of the ellipse is called its major axis. The small axis perpendicular to the major axis is called the minor axis.

How stretched out an ellipse is, can be quantified by a value called eccentricity. An ellipse's eccentricity is calculated by dividing the length between the ellipse's foci by the length of the major axis. If an ellipse has an eccentricity of zero, it is a perfect circle. If an ellipse has an eccentricity close to one, it is very long and narrow. Ellipses cannot have eccentricities greater than or equal to one, or less than zero.

While Kepler's First Law only mentions planets, it is true that it also applies to any other object that may orbit the Sun, including comets. One of the distinctive features of the comets we commonly see from Earth is that their orbits are generally much more eccentric than the orbits of the planets.

Topics

Orbits of objects in the Solar System
Geometry

Objectives

Students will:

- Create ellipses and use them as models of real orbits.
- Apply mathematics to determine properties of ellipses.
- Compare the orbits of planets and comets.

Overview

This activity introduces the geometrical concept of an ellipse to students. It asks them to use mathematics to generate their own ellipses, and then use these ellipses as orbital models of planets and comets.

Key Questions

How are the orbits of comets different than the orbits of the planets?
How are the orbits of long period and short period comets different?

Key Concepts

- All objects in orbit around the Sun travel in ellipses.
- Eccentricity describes how "stretched out" an ellipse is.
- The eccentricity of the orbits of comets are generally much different from the eccentricity of the orbits of the planets.

Materials & Preparation

Each student will need:

- A Student Worksheet entitled Cometary Orbits
- 25 cm x 30 cm piece of cardboard
- 3 blank, white sheets of 8.5 x 11 paper
- Pencil
- 20 cm long piece of string
- 2 push pins
- Pencil
- Ruler
- Tape

1. Review the student procedures, as listed on the Student Worksheet.
2. Collect corrugated cardboard boxes and cut out pieces approximately 25 cm x 30 cm.

3. Gather the materials listed above.
4. Make copies of the Student Worksheet.
5. Before starting this lesson, students must have a solid understanding of the properties of ellipses and how they relate to comets. Review the information in the Background section with the students. Explain that all objects in the Solar System travel around the Sun in an ellipse. If possible, show a diagram of the orbits of planets, asteroids, and comets as an example.
6. Choose student helpers to assist you in distributing the materials for the lesson.
7. Briefly demonstrate how to use the pencil, string, and thumbtacks to draw an ellipse. As a class, note the foci and major and minor axes of the ellipse.

Management

Push pins are sharp. Be sure to keep track of them closely and make sure that they have not fallen onto the floor or into a chair before moving on to the next lesson.

Reflection & Discussion

1. If the Sun is at one of the foci of an orbital ellipse, is there anything at the other focus?
2. What do you think an orbit with an eccentricity of 0.95 would look like? Of 0.25?

Transfer/Extension

1. Kepler's Third Law says that the square of the time it takes an object to orbit the Sun in years is equal to the cube of half of the length of the orbit's major axis, if the length of the axis is in astronomical AU. In other words:

   $(\text{Orbital Period in years})^2 = (1/2 \times \text{Length of Major Axis in AU})^3$
2. Using this formula, calculate the periods of the planet and comets in this activity.
3. An ellipse is an example of a "conic section." Investigate what a conic section is, and find examples of other conic sections.

Cometary Orbits

Student Procedures

1. Tie the ends of the string together so that they make a loop.

2. Fold the paper in half vertically and draw a vertical line on the fold to locate the mid-line of the paper.

3. Determine the midpoint of the vertical fold line. Mark the point with a pencil. This point will be the center of the ellipse.

4. Tape the corners of the piece of paper to the cardboard.

5. Put the yellow push pin into the cardboard at the midpoint.

Orbit of object	Distance between foci (cm)	Length of major axis (cm)	Eccentricity
Orbit 1	1cm		
Orbit 2	6cm		
Orbit 3	7cm		

6. Place the white push pin in the cardboard 1 cm from the yellow push pin.

7. Loop the string around the push pins.

8. Using your pencil, draw around the string, as shown in the diagram on page 10.

9. According to Kepler's First Law, what object in the Solar System should one of the foci represent? Label one of the foci this object.

10. Remove the white push pin and string from your diagram and label it "Orbit #1".

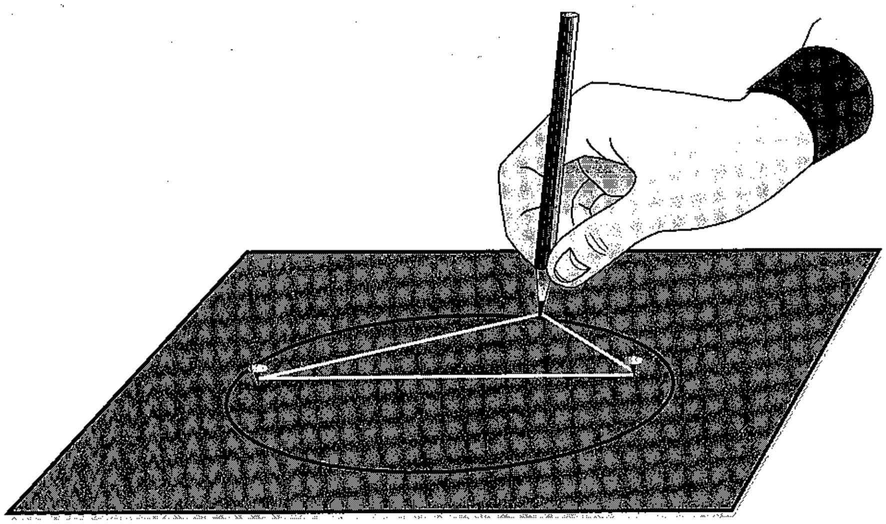
11. Repeat steps 6-9 for the rest of the orbits. The second time place the white push pin 6 cm from the yellow push pin in a different direction then the first. The third time place the white push pin 7 cm from the yellow push pin in a different direction than the first and the second.

12. When you are finished, measure the length of the major axes of each of the three orbits, in centimeters. Record your answers in the table. To ensure that you measure the full length of the major axis, line up your ruler along the ellipse's foci.

13. The eccentricity of an ellipse is given by the following equation:

$$\textbf{Eccentricity} = \frac{\textbf{distance between foci}}{\textbf{length of major axis}}$$

Use this equation to calculate the eccentricities of the three orbits. Record your answers in the table above.



Questions & Conclusions

1. Which of the objects in the table are most likely comets?

2. Which might be something else? What could it be?

3. Look at the shapes of the different orbits you have drawn and examine their relation to the Sun. How do you think Earth would be different if it had an eccentricity like that of object two or three?