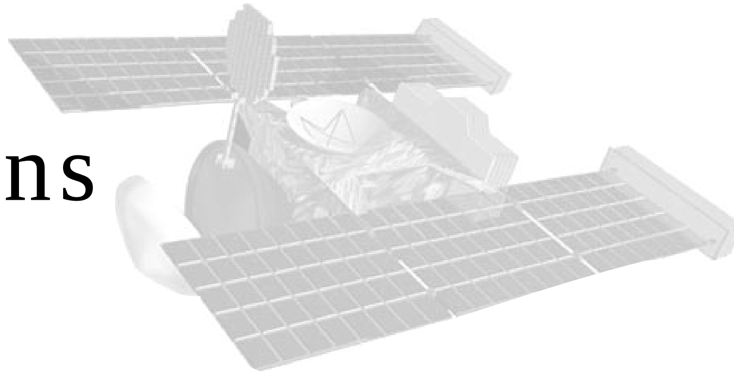
Comet Origins and Travels



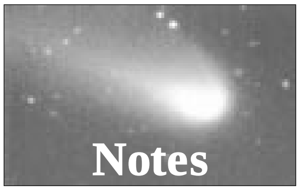
When comets are in the outer Solar System, beyond Neptune's and Pluto's orbit, they are small, dark, and so distant that detecting them is difficult. Still astronomers speculate that comets originate in a theoretical region called the Kuiper Belt and the Oort Cloud. Short-term comets, those with orbital periods less than 200 years, are said to originate in the Kuiper Belt. Those comets with periods greater than 200 years, and possibly thousands of years, are said to originate from the Oort Cloud. This section examines the origin of comets and characterizes their elliptical orbit through the Solar System.

- **Voyage of Discovery -** Walks students through a scale model of the Solar System over a 600 meter distance, beyond which comets originate.
- **Elliptical Orbits -** Draws an elliptical orbit using simple tools. Knowing a comet's elliptical orbit lets scientists predict where a comet will be at a given point in time, unless it gets pulled from its orbit by a giant gas planet.

Periodic Comet Wild 2 is new to the inner solar system. Before 1974, the comet was no closer to the Sun than Jupiter's orbit. When Wild 2 flew by Jupiter in 1974, the massive planet's gravitational force changed the comet's orbit; because of that it now travels closer to the Sun, between Jupiter and Earth.

By the time STARDUST encounters the comet, Wild 2 will have made only five trips around the Sun. By contrast, Comet Halley has passed the Sun more than 100 times. Since Wild 2 has passed by the Sun only a few times, it still has most of its dust and gases--we call that "pristine." This is important because comets are made up of material left over from the solar nebula after the planets were formed. Unlike the planets, most comets have not changed very much since the formation of the solar system. Therefore, comets hold the key to understanding the early development of the solar system. Wild 2 should contain much of this ancient material, making it an ideal choice for study.

STARDUST will fly close to Wild 2 and, for the first time ever, bring back material from a comet. This material will be collected from the coma and brought back to Earth to be analyzed. By analyzing this material, scientists may obtain clues to the formation of Earth, the solar system and perhaps even clues to the formation of other planetary systems.



Timeline

1 class for Part 1
1 class for Part 2

Key Question

How big is the Solar System if you could shrink it to one ten-billionth of its actual size?

Voyage of Discovery

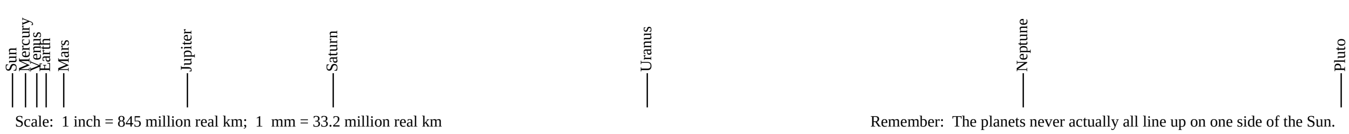
Overview

This activity has two parts: Exploring Planet Sizes and Walking Planet Distances. In the first part students find objects (food and candy) to match the sizes of the planets for a Solar System model on the one ten-billionth scale. The second part of the activity takes the students outside to walk the distances between the planets over a 600-meter area. Comet Wild 2 orbits between the orbits of Mars and Jupiter once every 6.17 years. Most comets originate beyond the orbits of Neptune and Pluto. This activity gives students the opportunity to observe the change in orbit of Comet Wild 2. Previously, its orbit lay between Jupiter and a point near Uranus, but after 1974 it changed to its current orbit between the orbits of Mars and Jupiter.

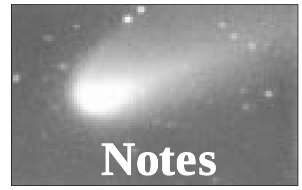
This activity is based on Challenger Center's Voyages Across the Nation, *a partnership between Challenger Center, the Smithsonian Institution, and NASA. This educational initiative is dedicated to fostering a deeper understanding of Earth's place in the Solar System, and the Sun's place among the stars. At the heart of* Voyages Across the Nation *are permanent outdoor exhibitions that depict the sizes and distances between the planets at one ten-billionth (1/10,000,000,000) the Solar System's actual size. The exhibitions' pedestals may display NASA color photographs, touchable model planets and moons, and encourage comparisons to Earth. The educational partners hope to place these exhibitions in communities around the nation.*

Objectives

- Demonstrate the size of the Sun and the bodies of the Solar System on the ten-billionth scale.
- Construct and walk the distances between the bodies of the Solar System on the ten-billionth scale.



NOTE: The planets all move at different speeds in their orbits around the Sun. They do not really appear in a straight line. Make sure students understand this concept.



Preparation

PART 1: EXPLORING PLANET SIZES

1. Gather materials needed.
2. Make copies of the Student Worksheets.
3. Do NOT hand out Model Planet Cards until teams finish the first Student Worksheet.
4. Prepare a master set of Model Planet Cards using the correct foods to use in Part II.

PART 2: WALKING PLANET DISTANCES

1. Find an area outside to walk 600 paces (600 meters or 0.4 mile) in a more or less straight line. Walk the distances to the planets yourself. This is important!
2. If the ground is soft, use pins to fasten the model planet cards; otherwise, use tape. If possible, get ten helium balloons and use these on the walk instead of the cards. You can see the balloons at a distance. Flags made of plexiglass on plywood stakes can also be used and they are reusable.

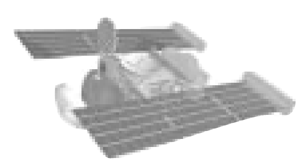
Materials Needed

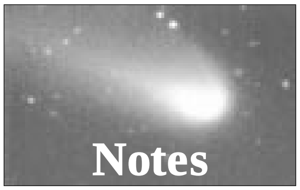
PART 1

- ❑ Balloon (for the model Sun)
- ❑ Metric ruler
- ❑ Miniature marshmallows
- ❑ Poppy seeds
- ❑ Mustard seeds
- ❑ Circle-shaped cereal
- ❑ Popcorn kernels
- ❑ Dried peas
- ❑ 1-cent gum balls
- ❑ Black pepper
- ❑ Glue
- ❑ Model Planet Cards

PART 2

- ❑ Voyage of Discovery Worksheet
- ❑ Pins or masking tape (ask your teacher)
- ❑ Pencil
- ❑ Hard writing surface (to take outside)





3. Students will need to bring Part 2 of their worksheets, pins or tape, a pencil and a hard writing surface on the walk.

Management

This activity has two parts, each of which can be completed in one class period.

Part 1 looks at the sizes of the planets and takes place in the classroom. Students predict the size of Earth and Jupiter and find foods (like cereal, gum balls, marshmallows, etc.) that are about the size of each planet. The foods are listed in the Materials List on the Student Worksheet. These choices are only suggestions; other foods will also work as models. Use whatever is convenient.

Part 2 requires the class to go outside to walk the distances between the planets. If possible, find a long stretch of land to walk the 600 meters. If not, a track will work, but it is not as dynamic.

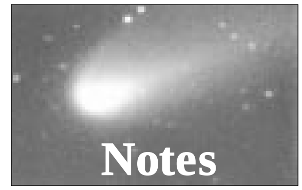
Walking the inner planets takes little time. Walking to Jupiter and each of the other outer planets takes much longer. Encourage a different team of students to be in charge of counting the paces out loud for one planet. Marking the place of each planet with a helium balloon is a good idea; you can see the balloons at a distance.

Procedure

PART 1: EXPLORING PLANET SIZES

1. Read through the Student Worksheet. This is where you will find the Materials List.
2. Discuss Earth, the Solar System, and why we need models to help study them.
   - Here is a riddle you can use:
     What is the biggest thing you have ever touched? Depending on where you can touch it, it can be wet or dry, hot or cold, and everybody you know has touched it, too. What is it?
   - Earth is the biggest thing we have ever touched, but Earth is not the biggest planet in the Solar System. We cannot just look up in the sky and see the whole Solar System and how it works. It is too big, and the planets are too far away.
   - Models let us take objects that are vast-bigger than we can understand-and bring them down to a size we can understand.
3. Show students the model Sun-the balloon blown up to 14 cm (5.5 in). Based on the size of the model Sun, students will work in teams of four or five to answer questions 1-5. These questions reveal what students think about planet sizes.
4. Discuss students' predictions and give them the answers.
5. Pass out the Model Planet Cards. Direct each team to glue the cereal, marshmallows, etc., to match the size of each planet.
6. Go around the room, having each team's reporter give reasons why they picked each object to use for a given planet.

7. Ask students to predict what size a comet is on this scale. Keep in mind that while comet sizes differ, they are generally the size of a city. So, on this scale a comet that does not have a tail is microscopic. Comets have the unique distinction of being one of the smallest and largest objects in the solar system. A comet's tail can at its longest extend the distance between the Sun and Earth. Students will find out how long this distance is during the second part of the activity.



8. Using the correct foods, prepare a master set of Model Planet Cards to use in Part 2. Let the glue dry and cut up cards for the walk. You may want to attach the cards to helium balloons for the walk to make the planets easy to see at a distance.

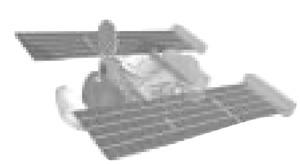
PART 2: WALKING PLANET DISTANCES

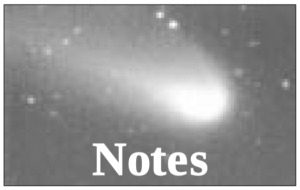
1. Before taking the class outside, introduce the "pace" as the "ruler" for this model. A pace is two steps-one with each foot. One pace is about 1 meter. You can use a meter stick for reference and for practice "pacing."
2. Have each team predict how far away the Earth card should be from the model Sun, using paces or meters.
3. Take your class outside to walk the model length of the Solar System. Take the cut-up master Model Planet Cards you made in Part 1.
4. For each planet, choose a team of students to be the official "pace setter" and "planet bearer" to fasten the planet at the correct distance.
5. Fasten the Sun to the ground (or tie a helium balloon to a nearby object). Tell the class the number of paces to Mercury, and tell students to complete the chart on their worksheets. "Walk" to Mercury, fasten the Mercury Planet Card to the ground, and repeat the process for all planets.
6. Ask the students questions from the Reflection Questions while walking the distances between the outer planets. These distances are large, so students' attention may wander. In this model, a spacecraft would move an average of 3 cm (1 in) every 5 hours.

NOTE: Be sure to point out the asteroid belt between Mars and Jupiter. Neptune was the most distant planet in the Solar System from 1979 until 1999 when Pluto passed outside of Neptune's orbit. Also be sure to tell students, once they reach Pluto, that most comets originate even farther away beyond the orbits of Neptune and Pluto.

7. Back in the classroom, conclude the activity with Reflection Questions.

NOTE: Be sure to remind students that the planets do not really form a straight line. They all travel around the Sun at different speeds, so they are constantly changing positions.





Reflection Questions

1. Did the position of Mercury surprise you?
2. How would the real Sun look from the real Mars compared to how we see the Sun from Earth?
3. Compare the sizes of the inner and outer planets.
4. How have we learned so much about the planets?
5. How fast do you think a spacecraft would travel on this model?
6. How do distances challenge spacecraft?
7. Were your predictions for the size of Earth and Jupiter right?
8. Were your predictions for the distance of the model Earth right?
9. What are some of the differences between the sizes of the inner and outer planets?
10. Why is Pluto so difficult to classify as either an inner or an outer planet?
11. What did you learn about the distances of the planets in the Solar System?

Worksheet Answer Key

Part 1

1. D
2. Jupiter
3. B
4. Mars, Mercury, and Pluto
5. Jupiter, Uranus, Saturn, and Neptune
6. These are suggestions for foods to use on the Model Planet Cards.
   Mercury and Mars: poppy seeds
   Jupiter and Saturn: miniature marshmallows, 1-cent gum balls, circular-shaped cereal
   Pluto: a piece of black pepper
   Venus and Earth: mustard seeds
   Uranus and Neptune: popcorn seeds or dried peas

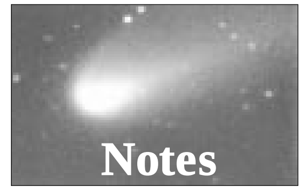
Part 2

1. Answers will vary.
2.

Walking From:	Paces (or meters) Between Models	Total Distance From Model Sun to Each Planet
Sun to Mercury	6 meters	6 meters
Mercury to Venus	5 meters	11 meters
Venus to Earth	4 meters	15 meters
Earth to Mars	8 meters	23 meters
Mars to Jupiter	55 meters	78 meters
Jupiter to Saturn	65 meters	143 meters
Saturn to Uranus	144 meters	287 meters
Uranus to Neptune	163 meters	450 meters
Neptune to Pluto	142 meters	592 meters

3. Answers will vary.
4. Answers will vary.

Voyage of Discovery Worksheet



PART 1: EXPLORING THE PLANET SIZES

Blow up a balloon to 14 centimeters in diameter. This balloon is a model Sun that is approximately one ten-billionth (1/10,000,000,000) the size of the real Sun. The questions below show planets that use the balloon as the scale model for the Sun.

> **Your Mission**
>
> You are scientists investigating the distances between the planets from your home planet, Earth. To do this, you must reduce the Solar System to a walkable distance, one ten-billionth of the size of the actual Solar System.

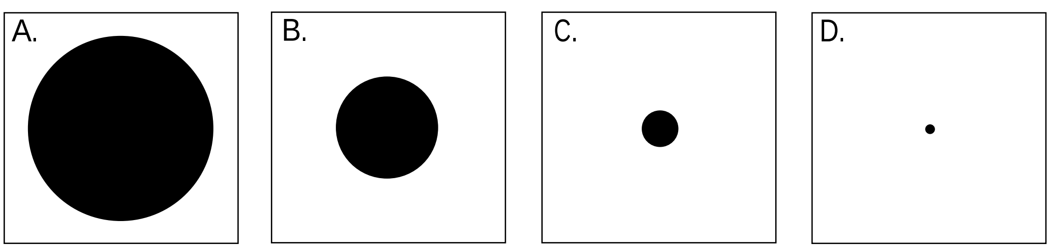
Roles

Decide which role each team member will assume:

- Leader: keeps the group on task.
- Materials Specialist: collects items on the Materials List.
- Recorder: writes down group answers.
- Reporter: speaks for the team.

Steps

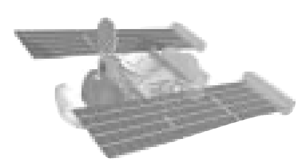
1. Predict which circle below you think represents the model Earth, if the balloon is the model Sun.

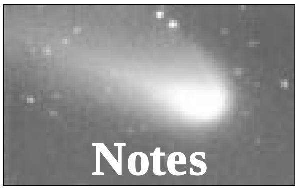


2. Which planet is the biggest? Circle one.

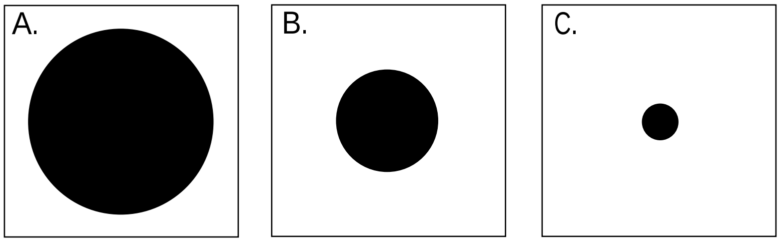
Earth Jupiter Mars Mercury Neptune

Pluto Saturn Uranus Venus





3. Which circle below do you think represents the biggest planet?



4. Look at the Model Planet Cards. What are the three smallest planets?

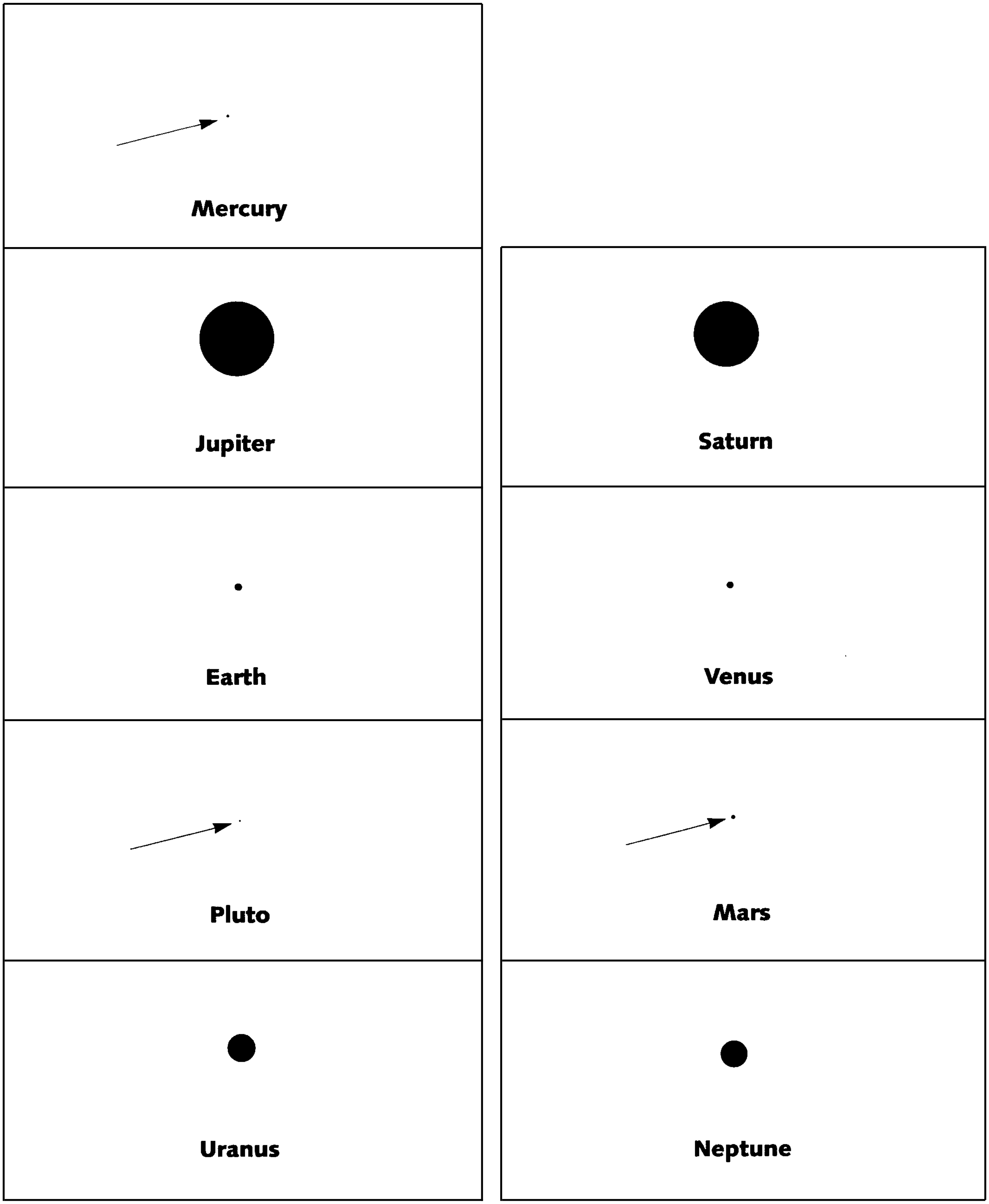
1. ______________________________
2. ______________________________
3. ______________________________

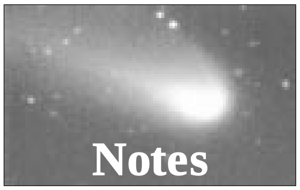
5. What are the four largest planets? These are called the gas giants.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

6. Using the items on the Materials List, match them to the size of the planets on the cards, and glue them to the right card.

Model Planet Cards





Part 2: Walking Model Planet Distances

1. Find your model Sun and model Earth. How far do you think the model Earth should be from the model Sun? State your answer in meters.

_____________________________meters

2. Walk the distances between the planets outside with your class and complete the chart below with your teacher's help.

MODEL DISTANCES CHART

Walking From:	**Paces (or meters) Between Models**	**Total Distance From Model Sun to Each Planet**
Sun to Mercury		
Mercury to Venus		
Venus to Earth		
Earth to Mars		
Mars to Jupiter		
Jupiter to Saturn		
Saturn to Uranus		
Uranus to Neptune		
Neptune to Pluto		

Warning: The planets never actually all line up to one side of the Sun. They orbit the Sun on different paths at different speeds. Some planets orbit in different planes.

3. What were you surprised to learn about the size of the planets?

____

____

4. What were you surprised to learn about the distances between the planets?

____

____

Elliptical Orbits

Overview

Almost everything orbiting the Sun travels in an ellipse. This activity has students explore ellipses of varying eccentricity using string, pushpins, and a pencil.

Objective

- ✥ Create ellipses and use them as models of real orbits.

Activity Preparation

1. Collect corrugated cardboard boxes and cut out pieces approximately 25 cm X 30 cm.
2. Gather materials.
3. Review the concept of orbits and ellipses with students.
4. Make copies of student worksheets.

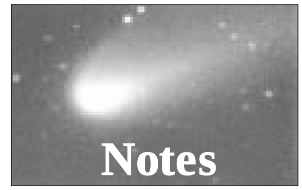
Management

Caution: Pushpins are sharp. Monitor their use closely and check to make sure that none have fallen to the floor before moving on to the next lesson.

Materials Needed

For each student:

- ❑ A copy of the Student Worksheet
- ❑ 25 cm x 30 cm piece of cardboard
- ❑ Three blank, white sheets of 8.5” x 11” (about 21 cm x 27 cm) paper
- ❑ Pencil
- ❑ 20-cm-long piece of string
- ❑ Two push pins
- ❑ Metric ruler
- ❑ Tape

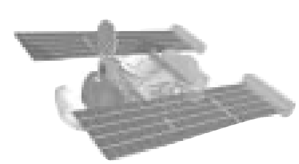


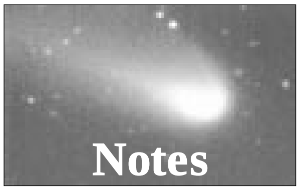
Timeline

1 to 2 classes

Key Question

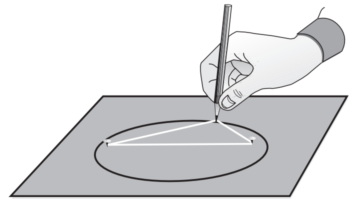
How do comets travel through the Solar System?





Procedures

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 in the materials section.
4. Make copies of the Student Worksheet.



Ellipse/Eccentric Orbits

All bodies orbiting the Sun travel in paths called ellipses. An ellipse looks like a stretched out circle. The amount an ellipse is stretched out is called its eccentricity. The orbits of most of the planets are shaped like circles that have been stretched out just a little. In other words, their eccentricity is low.

The planet Pluto has an orbit that is more stretched out than the orbits of the other planets. No one really knows why the planet Pluto’s orbit is more eccentric than those of the others, but there are many theories. Some scientists believe that Pluto was once a moon of the planet Neptune and was ripped from its orbit by a passing comet.

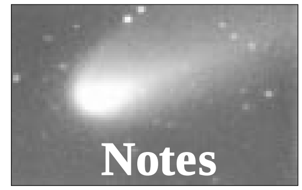
Comets, which have highly eccentric orbits, may take hundreds, even thousands, of years to complete one orbit around the Sun. As they near the Sun, they speed up; they slow down as they move to the outer regions of the Solar System beyond the planets. The elliptical orbit of a comet resembles the shape of a cigar.

The Sun’s mass provides the gravitational force which pulls objects around in their elliptical paths. Johannes Kepler, a scientist who lived in the early 1600s in Germany, discovered the relationship between the speed of a planet and its distance from the Sun. He noticed that as an object gets closer to the massive Sun, it is pulled around faster. Also, the farther away a planet is from the Sun, the more slowly it moves around in its orbit. For example, Mercury, the planet closest to the Sun, orbits in just under 88 days, while Neptune and Pluto are the farthest planets from the Sun and take over 100 years!

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.

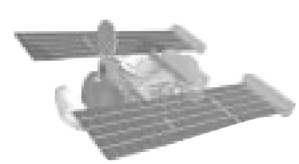
Reflection Questions

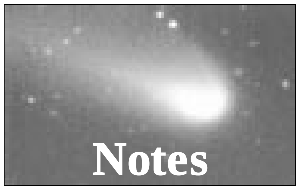
1. If the Sun is at one of the foci of an orbital ellipse, is there anything at the other focus?
2. What do you think an orbit with an eccentricty of 0.95 would look like? Of 0.25?



Answer Key

1. Focal points
2. The eccentricity of the circle is 0. The eccentricity of ellipse 1 should be a number between 0 and 1. Answers will vary slightly because of measurement errors. The eccentricity of ellipse 2 will be greater than ellipse 1 but still a number between 0 and 1.



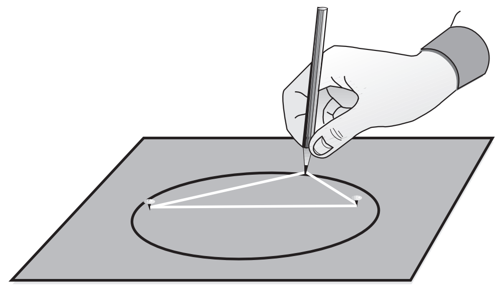


Elliptical Orbits

Name________________________________ Date _________________________

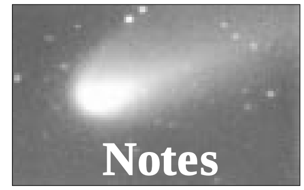
Steps

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 carboard at the midpoint.
6. Place the white push pin in the cardboard 1 cm from the 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.
9. Remove the white push pin and string from your diagram and label it “Orbit #1.”
10. 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 than the first.

Questions



1. The orbits of the planets and comets around the Sun all are shaped like ellipses. Ellipses have two ______________________________ .

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

$$\text{Eccentricity} = \frac{\text{Distance between foci}}{\text{Length of major axis}}$$

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

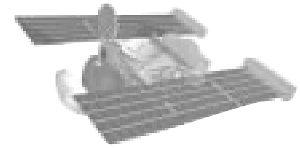
Orbit	Distance Between Foci (cm)	Length of Major Axis (cm)	Eccentricity
Orbit 1	1 cm		
Orbit 2	6 cm		
Orbit 3	7 cm		

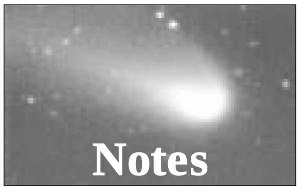
3. According to Kepler's First Law, what object in the Solar System should one of the foci represent? __________ .

4. A circle is a form of ellipse with its eccentricity equal to ____________ .

Why . . .

In our Solar System, objects orbit the Sun in paths that are shaped like ellipses, with the Sun at one of the focal points. Some of the orbits in the Solar System are shaped more nearly like a circle and others have a more eccentric orbit. In other words, the focal points of their ellipses are farther apart. Some comets have very eccentric orbits, traveling near the Sun during part of their orbits, and beyond the outer planets at other points in their orbits. Knowing about orbits helps us to predict the positions of planets and chart courses for spacecraft.

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