SESSION 3.10

Human-powered Orrery

Overview

An orrery is a model of the Solar System that illustrates the relative motions and positions of bodies in the Solar System. The name comes from Charles Boyle, the 4th Earl of Orrery, for whom one of these models was made. The first orreries were mechanical, but a computer model of the Solar System, such as the one on the Space Science Sequence CD-ROM, is also called an orrery. In this session, the class works together to create a human-powered orrery to model the movements of the four inner planets. Students assist in setting up this moving model of the Solar System and take turns playing the roles of Mercury, Venus, Earth, and Mars. As the class observes the orrery in motion, they form conclusions about the orbital periods of the inner planets. Afterward, the class predicts the orbital periods of the outer planets using the mapped scale model transparency from Session 3.9. During this session, the key concepts that will be added to the classroom concept wall are:

- ***Planets closer to the Sun have smaller orbits and move more quickly than planets farther from the Sun.***
- ***Objects in the Solar System are in regular and predictable motion.***
- ***As seen from Earth, the positions of the planets and the Sun are always changing.***

Human-powered Orrery	Estimated Time
Setting Up and Running the Orrery	35 minutes
Reflecting on Planetary Motion	10 minutes
Total	**45 minutes**

What You Need

For the class:

- ❑ overhead projector or computer with large-screen or LCD projector
- ❑ (optional) Space Science Sequence CD-ROM
- ❑ prepared key concept sheets from the copymaster packet or CD-ROM file
- ❑ transparency of the map with outer planet orbits drawn in (from Session 3.9)
- ❑ a 2.5 meter piece of thin rope or string (made out of a material that is not stretchy)
- ❑ (optional) 36 meters (120’) of rope (e.g. cotton clothesline)
- ❑ 5 index cards (4"x6")
- ❑ marble or bead, close to 1.4 cm in diameter
- ❑ several rolls of masking tape or blue painter’s tape or chalk

Unit Goals

The Solar System is centered around the Sun, the only star in the Solar System.

A wide variety of objects orbit the Sun in the Solar System.

Scientists categorize Solar System objects according to their characteristics; however, not all objects can be easily categorized.

Objects in the Solar System are in regular and predictable motion.

The Solar System is mostly empty space, and is very large compared to the objects located within it.

TEACHER CONSIDERATIONS

TEACHING NOTES

More about the orrery. An orrery is a moving model of the Solar System that includes the Sun and planets and sometimes the moons of the planets. It is used to demonstrate the motions and positions of objects in the Solar System. Around 1704, one of the first orreries was designed by George Graham, an engineer and inventor. It was built by John Rowley, a maker of scientific instruments. The orrery was given as a gift to Charles Boyle, the 4th Earl of Orrery. It was the Earl whose name stuck to the device.

In a spatial sense, the human-powered orrery is a two-dimensional model. (Although the participants in the orrery are three-dimensional, they are representing the orbits of the planets on a flat, two-dimensional surface.) This model is, however, three-dimensional in the sense that it changes through time. Two dimensions of space and one dimension of time make up the three dimensions.

The Space Science Sequence CD-ROM has an interactive orrery of the outer Solar System (CLICK on the Moving Planets activity), which you may find useful in demonstrating orbital movement to your students. The animation may not be necessary for older or more advanced students.

Key Vocabulary

Scientific Inquiry Vocabulary

Category
Characteristic
Evidence
Model
Observation
Prediction
Scale
Scale model
Scientific explanation

Space Science Vocabulary

Asteroid
Astronomical Unit (AU)
Comet
Diameter
Heliosphere
Kuiper Belt Object (KBO)
Moon
Orbit
Planet
Sphere
Star
System

The gym, cafeteria, multi-purpose room, music room, school lobby, or paved outdoor schoolyard are all possible location options for this activity.

These scaled planet orbit distances are one-hundredth of the distances used for the outdoor scale model in Session 3.8.

For each team of 4-6 students:

- ❑ scratch paper
- ❑ pencil

Getting Ready

1. **Prepare the key concept sheets.** Make a copy of each key concept and have them ready to post onto the classroom concept wall during the session.

2. **Find a clear space at least five meters (about 17 feet) square for the orrery.** It doesn't matter whether the space is located indoors or outdoors, as long as it has a smooth surface that can be marked with tape or chalk.

3. **Tie knots in the rope corresponding to the orbits of the inner planets.** Tie a large knot at one end of the rope. This will indicate the starting point of the model—the Sun. Measuring from this first knot out, tie four more knots at the distances along the rope for each planet's orbit radius indicated in the Orrery Table on this page. (Note: These distances are all distances from the Sun's knot, NOT the distances between the knots themselves!)

4. **Have several rolls of masking tape, blue painter's tape, or chalk on hand.** The tape will be used to mark out the orbits of the planets. Choose tape that is at least one inch wide and a color that contrasts with the color of the surface on which the class will be working. If the model will be staged outdoors on a paved surface, chalk is an easy and convenient alternative to tape.

5. **Make signs for the Sun and inner planets.** On an index card, write "SUN" in large, bold lettering. Tape the marble to the sign. Use the other cards to make signs labeled "MERCURY," "VENUS," EARTH," and "MARS." Put a tiny dot, much less than a millimeter across, on each sign to represent each planet.

Orrery Table (Dimensions)

Planet	Radius (cm)	Circumference (cm)	Circumference (in ft)	2-week Pace Length (cm)
Mercury	58	364.42	11.96	60.7
Venus	108	678.58	22.26	42.4
Earth	150	942.48	30.92	36.2
Mars	228	1432.57	47.00	28.7
		Total rope needed:	112.14	

TEACHER CONSIDERATIONS

TEACHING NOTES

The key concepts can be posted in many different ways. If you don't want to use sentence sheets, here are some alternatives:

- Write the key concepts out on sentence strips.
- Write the key concepts out before class on a posted piece of butcher paper. Cover each concept with a strip of butcher paper and reveal each one as it is brought up in the class discussion.

Alternatives for Setting Up the Orrery

Orrery Alternative A. Students make tape or chalk marks.

It is easy and fast to set-up the orrery with many pairs of hands helping you out, and the process of marking the orbits is one your students may find educative.

Orrery Alternative B. Teacher/helpers make circumference ropes.

This alternative is the most efficient in terms of class time needed to set up the orrery. As preparation, make four rope loops of the proper lengths for each planet orbit circumference, as shown in the Orrery Table on page 504. Fasten pieces of tape to the ropes at the 2-week-pace-length indicated for each planet.

Orrery Alternative C. Teacher/helpers put orrery marks on floor as prep.

1. Tie knots: one at one end of the rope (for the Sun's position), and a knot for each of the orbit radii show in the Orrery Table on page 504. These are distances from the ***Sun's knot***, NOT the distances between the knots themselves!
2. Have chalk or tape pieces ready. If using tape, you need 6 pieces for Mercury's orbit, 16 for Venus, 26 for Earth, and 50 for Mars.
3. Cut four pieces of cardboard to measure the correct 2-week-pace-length between tape pieces (or chalk marks) for each planet's orbit. Use lengths indicated in the 2-week-pace column of the Orrery Table.
4. Mark the orbit for each planet on the floor/ground as follows:
   - Make an X using the tape (or chalk) to represent the Sun's position.
   - Place the "Sun knot" end of the rope at the X, and stretch the rope straight out to the appropriate knot (e.g., at 58 cm, for Mercury). Make sure that the "Sun knot" remains on the X. Place a piece of tape (or use the chalk) to mark the position of the first knot on the ground.
   - Using the appropriate 2-week-distance cardboard (e.g., 61 cm for Mercury) place a second tape (or chalk) mark on the ground at the other end of the 61 cm cardboard strip. Continue measuring 2-week distances and placing tape (or chalk) marks until you have all marks for the planet (e.g. 6 for Mercury). Use the knotted orbit radius rope to make sure that the tape (or chalk) marks are all the right from the "Sun".

6. **Recruit additional people if necessary.** Setting up the orrery itself is an integral part of this session and requires the participation of at least 26 people. If you don't have that many students, try to find additional people such as other faculty members, teacher's aides, or students from other classes to help with this activity.

7. **Decide how you will divide the class into teams of 4–6 students for the Reflecting on Planetary Motion discussion.**

8. **Optional: If you are planning to show the CD-ROM orrery animation (in the Moving Planets activity), set up a computer with a large-screen monitor or LCD projector.**

GO! Setting Up and Running the Orrery

1. **Remind students of the scale models from Sessions 3.8 and 3.9.** Ask students to think back to the outdoor scale model of the inner planets and the mapped scale model of the outer planets. Have students describe their impressions of the scale of distances in the Solar System. [Uncrowded, mostly space, pretty empty.] Point out that these scale models allowed the class to visualize the vast distances between the planets of the Solar System.

2. **Tell students that today they will construct another scale model to observe the movements of the planets more closely.** Remind students that at the end of the last session, they observed the swirling cloud model and saw how an ordered system could be formed from a disordered one. Tell them that today they will observe another moving model of the Solar System, called an *orrery*. This model will allow them to look more closely at the movements of the planets around the Sun.

3. **The scale of the orrery.** Today's model will be *one-hundred billionth* the size of the actual Solar System. Remind students that the outdoor scale model was one-billionth the size of the Solar System, so this model is one-hundredth the size of that model.

4. **Explain the scale of the Sun and planets in this model.** Show students the sign that says "SUN" with the marble taped to it. Tell them that the diameter of the marble is about one one-hundred billionth the diameter of the Sun. The size of the Sun and the sizes of the planets' orbits *will be* to scale. Show the signs for the four inner planets. The planets will be represented by tiny specks, which *are not* to scale. They are too large! Explain to the class that the focus of today's model is on the *movement* of the planets and not the sizes of the planets, so scaled sizes are not as important.

TEACHER CONSIDERATIONS

TEACHING NOTES

A note about Setting Up and Running the Orrery: This is a particularly detailed activity. In order to make the presentation write-up easier for you to follow, additional section sub-headings have been added:

- Modeling Mercury's Movement
- Comparing the Movements of Mercury and Venus
- Setting the Orbits of Earth and Mars
- Running the Model of the Inner Solar System

Note that these subheadings are **not** listed in the session timetable. The 35 minutes allotted for Setting Up and Running the Orrery includes them.

Running the orrery may pose some class-management challenges. Listed below are a few suggestions and ideas that may address some of the most common behavioral issues with this activity.

Maintaining student interest. Involve your students in all aspects of the orrery. When describing a student's role in the orrery, address the entire class, not just the student. Give everyone in the class a chance to participate by constantly changing student roles—allow several different students the chance to play the role of the Sun or one of the moving planets. Clapping and chanting "two weeks" in unison helps to center and focus the group. During the activity, pose observation questions to the students who are not involved in the orrery directly and make a mental note to swap those students into the moving orrery at some point.

Managing the class. Be prepared to deal with class-management issues during this activity. If you know that this will be a significant issue, consider showing the class the orrery animation on the Space Science Sequence CD-ROM (CLICK on the Moving Planets activity) instead of having them run the orrery themselves.

5. They will all play important roles in the orrery. Tell the class that today's activity is called the Human-powered Orrery, and that everyone will be an integral and important part of the moving model!

One teacher said, "I kept having the planets race around the Sun, and despite numerous attempts, Mercury kept winning. Thanks for taking a really tough abstract concept and making it easy for the kids to understand."

Modeling Mercury's Movement

1. Move the class to the space chosen for the orrery. Take the knotted rope, tape or chalk, and cardboard signs with you.

2. Have students stand in a circle. In the center of the circle, mark an X with the tape or chalk. Tell the class that the X represents the position of the Sun. Select a student to be the Sun and have him or her stand on the X in the middle of the circle with the "SUN" sign. Remind the class that in this model the size of the Sun and sizes sizes of planet orbits are to scale, but not the sizes of the planets themselves.

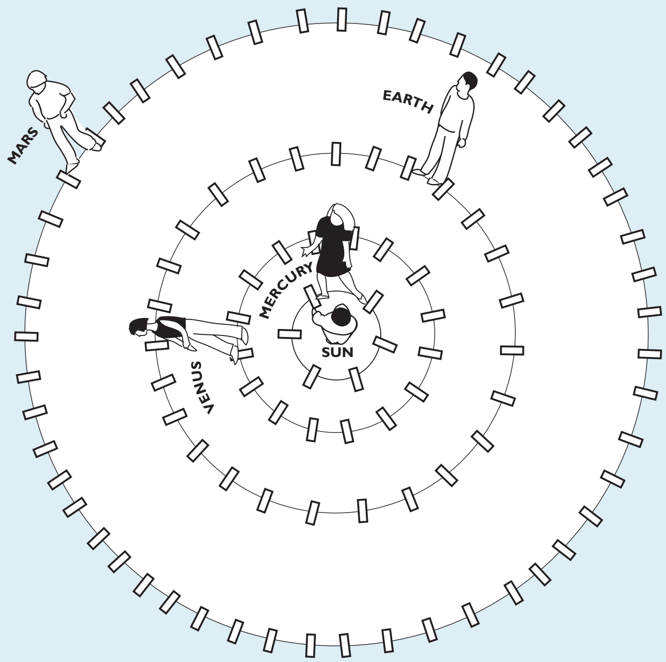
3. Select six students to help form the orbit of Mercury. Assure the class that everyone will have a chance to participate in the model at some point.

4. Remind the class of the scale of the model. Tell the class that since today's scale model is only one-hundredth the size of the previous scale model, the distances of the planets from the Sun will also be one-hundredth the distances that they were in the other scale model. Show the class the length of knotted rope and tell them that each of the knots on the rope represents the scaled distance of a planet from the Sun.

5. Set the size of the orbit of Mercury. If using Orrery Alternative A, give each Mercury student a short piece of tape (about 4" long) or a piece of chalk and have them form a circle around the Sun. Have the Sun student hold onto the knot at the end of the rope. Hold onto the first knot (tied 58 centimeters from the Sun's knot) and walk in a circle around the Sun, making sure to pull the rope taut as you delineate Mercury's orbit. The Sun student should turn with you as you walk around. Ask the six Mercury students to space themselves evenly around the Sun along the orbit's path. Once all six are in place, have them each mark their position with their tape or chalk, and then have them rejoin the larger class circle.

If using Orrery Alternative B, have the Mercury students help spread out the Mercury circumference rope in a circle with the Sun at the center.

HUMAN-POWERED ORRERY



Mercury: 58 cm from Sun / 6 pieces of tape
Venus: 108 cm from Sun / 16 pieces of tape
Earth: 150 cm from Sun / 26 pieces of tape
Mars: 228 cm from Sun / 50 pieces of tape

TEACHING NOTES

Give as many students as possible an opportunity to participate in the orrery. Choose one student to be the Sun for now, but swap in other students for the Sun's role throughout the activity.

Consider allowing different students to set the orbits of the planets using the knotted rope. This option allows more students to participate in the orrery and can help maintain student engagement in the activity. You may first want to demonstrate to the class by setting Mercury's orbit and then allowing students to set the orbits of the other inner planets.

6. **Choose a student to represent Mercury.** Have the student stand on one of the tape or chalk marks along Mercury's orbit with the "MERCURY" sign. Ask the class how Mercury moves around the Sun. [It spins while orbiting the Sun.] Tell students that even though the planets do spin around an axis, they will not be modeling this today. Instead, today's model will focus on just the orbital movements of the planets.

7. **Modeling Mercury's orbital movement.** Tell the class that just as the model has a distance scale, it also has a time scale. The time represented between each tape mark is about two Earth weeks. Have the Mercury student step from tape mark to tape mark around the Sun in a counterclockwise orbit. Ask the class how many weeks it would take Mercury to make a full orbit around the Sun using this time scale. [12 Earth weeks.] Ask the Sun and Mercury students to hand you their signs and rejoin the larger class circle.

Comparing the Movements of Mercury and Venus

1. **Select 16 students to help form the orbit of Venus.** Also choose a new student to represent the Sun.

2. **Set the size of the orbit of Venus.** If using Orrery Alternative A, Give each Venus student a short piece of tape or a piece of chalk and have them form a circle around the Sun that is larger than Mercury's orbit. Have the Sun student hold onto the knot at the end of the rope. Hold onto the second knot (tied 108 centimeters from the Sun's knot) and walk in a circle around the Sun, making sure to pull the rope taut as you delineate Venus' orbit. Again, the Sun student should turn with you as you walk around. Ask the 16 Venus students to space themselves evenly around the Sun along the orbit's path. Once all 16 students are in place, have them each mark their position with their tape or chalk and then have them rejoin the larger class circle.

   If using Orrery Alternative B, have the Venus students help spread out the Venus circumference rope in a circle with the Sun at the center.

3. **Students compare Mercury's tape marks to Venus' tape marks.** Have students describe how the tape marks are spaced. [Venus' tape marks are closer together than Mercury's tape marks.] Ask the class how much time is represented between each tape mark. [Two Earth weeks.] Ask the class which planet, Mercury or Venus, will move a greater distance in a two-week time period. [Mercury.]

TEACHER CONSIDERATIONS

TEACHING NOTES

You may want to explain how unusually Mercury moves. Mercury spins completely around three times for every two orbits it makes around the Sun.

About the terms *rotation* and *revolution*. Traditionally, students have been taught to use the word *rotation* to describe the spinning of a planet and the word *revolution* to describe the planet's movement around the Sun. For example: "The Earth *rotates* on its axis and *revolves* around the Sun." In other contexts, the words *revolve* and *rotate* can take on slightly different and confusing meanings. *Revolve* often means "to spin," as in a "revolving door." *Rotate* can be used to mean "to follow a cyclical path or system," as when a certain task or responsibility is rotated among several people. The terms *spin* and *orbit* are scientifically accurate alternatives that are clearer to students.

Having the class clap and announce the time scale together is an excellent way to focus all students on the activity at hand.

4. **Run the model with Mercury and Venus.** Choose two students to represent Mercury and Venus and pass out the signs. Explain that both planets must move around the Sun according to the same time scale. To help the two planets synchronize their movements, the class will clap and announce "two weeks." With each clap, Mercury and Venus should move along their orbits from one tape mark to the next, counterclockwise around the Sun. Start off slowly at first, clapping about once every two seconds. Pick up the pace after a couple of claps.

5. **Comparing Mercury and Venus.** After a dozen or so claps, stop the class and ask, "If Mercury and Venus were racing around the Sun, who do you think would win the race?" [Mercury.] Have the students who are representing the Sun, Mercury, and Venus hand you their signs and rejoin the larger class circle.

Setting the Orbits of Earth and Mars

1. **Select 26 students to help form the orbit of Earth.** Also, choose a new student to represent the Sun.

2. **Set the size of the orbit of Earth.** If using Orrery Alternative A, give each Earth student a short piece of tape or a piece of chalk and have them form a circle around the Sun that is larger than Venus' orbit. Have the Sun student hold onto the knot at the end of the rope. Hold onto the third knot (tied 150 centimeters from the Sun's knot) and walk in a circle around the Sun, making sure to pull the rope taut as you delineate Earth's orbit. The Sun student should turn with you as you walk around. Ask the 26 Earth students to space themselves evenly around the Sun, along the orbit's path. Once all 26 students are in place, have them each mark their position with their tape or chalk and then rejoin the larger class circle.

   If using Orrery Alternative B, have the Earth students help spread out the Earth circumference rope in a circle with the Sun at the center.

3. **Have students compare orbits of Mercury, Venus, and Earth.** Students should note that the tape marks in Earth's orbit are closer together than the tape marks in Venus' orbit. Ask students whether Earth will move slower or faster than Venus. [Slower.] Ask students to predict whether Mars will move faster or slower than Earth.

This makes a circle of 50 marked steps for the orbit of Mars. (In reality, 49 tape marks would be more accurate, but it's easier to set the orbit of Mars with an even number of marked steps.)

4. **Select 25 students to help form the orbit of Mars.** If using Orrery Alternative A, give each Mars student *two* pieces of tape or a piece of chalk. Just as before, have the Sun hold onto the knot at the end of the rope while you walk out a 228-centimeter orbit around the Sun. Ask the 25 Mars students to space themselves evenly around the Sun, along the orbit's path. Once all 25 students are in place, have them each mark their position with tape or chalk. Then they should each shift half a space to their right and mark another position halfway between the marks on either side. Have the students rejoin the larger class circle.

   If using Orrery Alternative B, have the Mars students help spread out the Mars circumference rope in a circle with the Sun at the center.

Running the Model of the Inner Solar System

1. **Select students to represent Mercury, Venus, Earth, and Mars.** Pass out the signs and have the students representing the four inner planets all step to a marked position in their orbit on the same side of the Sun. The planets should be lined up as if they are about to begin a race. Emphasize that this is an unusual planetary alignment. Have students make predictions about the rates of movement of the four inner planets. Ask, "If the planets were racing to complete their orbits around the Sun, which planet would you want to be if you wanted to win this race?" [Mercury.]

2. **Run the model.** Have everyone begin clapping together. Lead the class in chanting "two weeks" with each clap. Stop the class after 26 claps. Point out that Earth has made one full orbit around the Sun. Ask the class how many weeks have passed. [52 weeks, or one year.] Have students describe the progress of the other planets and how much time has gone by for them.

3. **If time allows, continue running the model with different students.** Try to make sure that everyone in the class gets a chance to participate in the orrery. Solicit comments and observations from students as they observe the model in action. Return to the classroom 10–15 minutes before the period ends.

Reflecting on Planetary Motion

1. **Divide students into teams of 4–6.** Give each team a pencil and a piece of scratch paper. Ask them to list any "true statements" they can make after observing the movements of the planets in the orrery. After a few minutes, call on each team to read one of its statements aloud.

2. **Different planets require different amounts of time to complete**

If you used strips of tape for marking the orbits, ask students to help remove the tape from the ground. Alternatively, if you are planning to run the orrery with more than one class, you could leave the tape marks where they are. (This option would not allow the next class to participate in the orrery setup.)

one orbit around the Sun. Ask teams to discuss whether it is the length of the planet's orbit or the speed at which the planet moves that makes the difference in the time it takes to make a full orbit. [Both the speed of the planet and the length of its orbit contribute.]

3. **Considering the *year lengths* of the inner planets.** Ask students what the term *year length* might mean. [A year is defined as the amount of time it takes for a planet to complete its orbit around the Sun.] Ask students to think back to the orrery and the year lengths of the four inner planets. Ask, "Which planet has the shortest year length?" "Which planet has the longest year length?" [Mercury has the shortest. Mars has the longest.]

4. **Looking at the outer planets.** Display the overhead transparency from Session 3.9 that shows the mapped orbits of the outer planets. Ask the class why the orrery included only the orbits of the inner planets. [The orbits of the outer planets are spread out even more than those of the inner planets. Even scaled down to one-hundred billionth of their real size, the orbits of the outer planets would not fit within the schoolyard.]

5. **Discussing the *year lengths* of the outer planets.** Ask students what they might predict about the year lengths of the outer planets. [They are very long—longer than the year lengths of the inner planets.] Read off the year lengths of the planets to the class:

   Mercury's year = 12 Earth weeks or 0.2 Earth years
   Venus' year = 32 Earth weeks or 0.6 Earth years
   Mars' year = 2 Earth years
   Jupiter's year = 12 Earth years
   Saturn's year = 29 Earth years
   Uranus' year = 84 Earth years
   Neptune's year = 165 Earth years

6. **Optional: Show the class the orrery animation (click on the Moving Planets activity) on the Space Science Sequence CD-ROM.**

7. **A pattern to the year lengths.** Ask students if they notice a pattern or trend between the location of the planets and their year lengths. [The farther away from the Sun a planet is, the longer its year length.] Ask students why they think that planets closer to the Sun have smaller year lengths. [These planets have smaller orbits and they move more quickly than the planets farther out from the Sun.] Post on the concept wall, under Key Space Science Concepts:

   Planets closer to the Sun have smaller orbits and move more quickly than planets farther from the Sun.

TEACHER CONSIDERATIONS

CD-ROM NOTES

SESSION 3.10: ORRERY ACTIVITY OF THE OUTER SOLAR SYSTEM

Use this interactive animation to simulate the class orrery with the outer planets of the Solar System. Each colored robot represents one of the outer planets. The user has three options in running this orrery:

1) Have the planets move along their orbits in increments of two weeks.
2) Have the planets move along their orbits in increments of one Earth year.
3) Have the planets move along their orbits continuously.

Elapsed time as counted in Earth weeks is displayed in the lower right corner of the screen. To enlarge the interactive to full screen, press CONTROL F (Windows) or APPLE F (Macs). Press ESC to exit the full-screen display.

8. **Viewing the movements of the planets from the Sun.** Ask the class how the movements of the planets would appear to someone standing in the position of the Sun. [The planets would appear to move in an organized and orderly manner around the Sun. The viewer would see a consistent pattern in the motion of the planets.] Post on the concept wall, under Key Space Science Concepts:

   Objects in the Solar System are in regular and predictable motion.

9. **Viewing the movements of the planets from the Earth.** Now ask the class to visualize how the movements of the planets might appear to someone standing in the position of the Earth. [Since Earth is not in the center of the Solar System and is also constantly moving itself, the movements of the planets would seem complex to an observer on Earth.] Post on the concept wall, under Key Space Science Concepts:

   As seen from Earth, the positions of the planets and the Sun are always changing.

10. **Conclude by having teams list the accuracies and inaccuracies of the orrery.** Some things the model showed accurately:

    - All the planets orbited the Sun in the same direction. (Use this opportunity to remind the class of the swirling cloud model from Session 3.9.)
    - All the planets' orbits were in the same plane. (This is roughly true in the Solar System. The planes in which each planet orbits are different from each other by a few degrees.)
    - The orbits were all close to circular. (The orbits of all the Solar System's planets are close to circular, but each is slightly elliptical. The orbit of Mercury is noticeably more elliptical than the other orbits.)
    - The inner planets moved faster and had shorter orbits than the outer planets.

    Some things the model showed inaccurately:

    - The sizes of the planets were not to scale.
    - The planets did not spin.

TEACHER CONSIDERATIONS

PROVIDING MORE EXPERIENCE

If your students are able to quickly grasp the essential points of this model, and you wish to have a more extensive discussion, here are some additional and more subtle topics you can discuss with the class:

- **Orientation of the Sun, Earth, and Mars.** About every two Earth years, the Earth passes between the Sun and Mars. When this occurs, Mars appears high in the sky at midnight. If the Sun is between the Earth and Mars, Mars will not be visible at any time of day from Earth. Ask your students to try and explain these two scenarios.
- **Rising and setting of Mercury and Venus.** Earth will never pass between the Sun and Mercury or between the Sun and Venus. As a result, these planets are never visible from Earth at midnight. During an Earth day, Mercury and Venus rise and set fairly close to the time that the Sun rises and sets. These two planets are visible in a dark sky only shortly before sunrise or shortly after sunset. (Venus is often called the "evening star" or the "morning star.") Ask your students to try to explain these observations about Mercury and Venus.
- **Minimizing the traveling distance to Mars.** Ask students to think about how scientists planning a trip to Mars might minimize the distance required to make the trip.
- **Conjunctions.** When the Earth, Sun, and another planet are all lined up, the other planet is said to be in conjunction. If the planet is on the opposite side of the Sun from Earth, then the conjunction is called a superior conjunction. If the planet is on the same side of the Sun as Earth, then the conjunction is called an inferior conjunction.
- **Transits.** When a planet is in inferior conjunction and is nearly perfectly in line with the Earth and Sun, it appears right in front of the Sun and looks like a tiny black spot on the Sun. This is called a transit of the Sun by that planet. Only two planets can ever transit the Sun. Ask your students which two planets can transit the Sun.