Human-Powered Orrery

TEACHER GUIDE

An orrery is a mechanical model of planets in the Solar System that illustrates the relative motions and positions of the planets. In this activity, you create an orrery with humans modeling the movements of the four inner planets. It is not 1-dimensional like most classic solar system models. It's THREE-dimensional:

2 dimensions of space for the orbit
(at scale of about 1 cm = 150 million km), and
1 dimension of time (at scale of about 1 sec = 2 weeks).]

Get Ready! Materials and Preparation

- a clear space at least 5 meters (16 feet) square
- four rope loops with pieces of tape attached (circumferences and spacings given in chart below).
  Ideal colors of tape pieces:
  Mercury-gray or white; Venus-yellow;
  Earth-blue or green; Mars-red
- bead to show the scale size of the Sun (≈14 mm)
- 1 copy per student: Observation Sheet (with Orrery Questions)

Orrery Orbit Measurements

Planet	Radius (cm)	Circumference (cm)	(feet)	2-week pace (cm)	# of paces in a year
Mercury	58	364	12	60	6
Venus	108	679	22	42	16
Earth	150	942	31	36	26
Mars	228	1433	47	29	50
	Total:	3414	112		

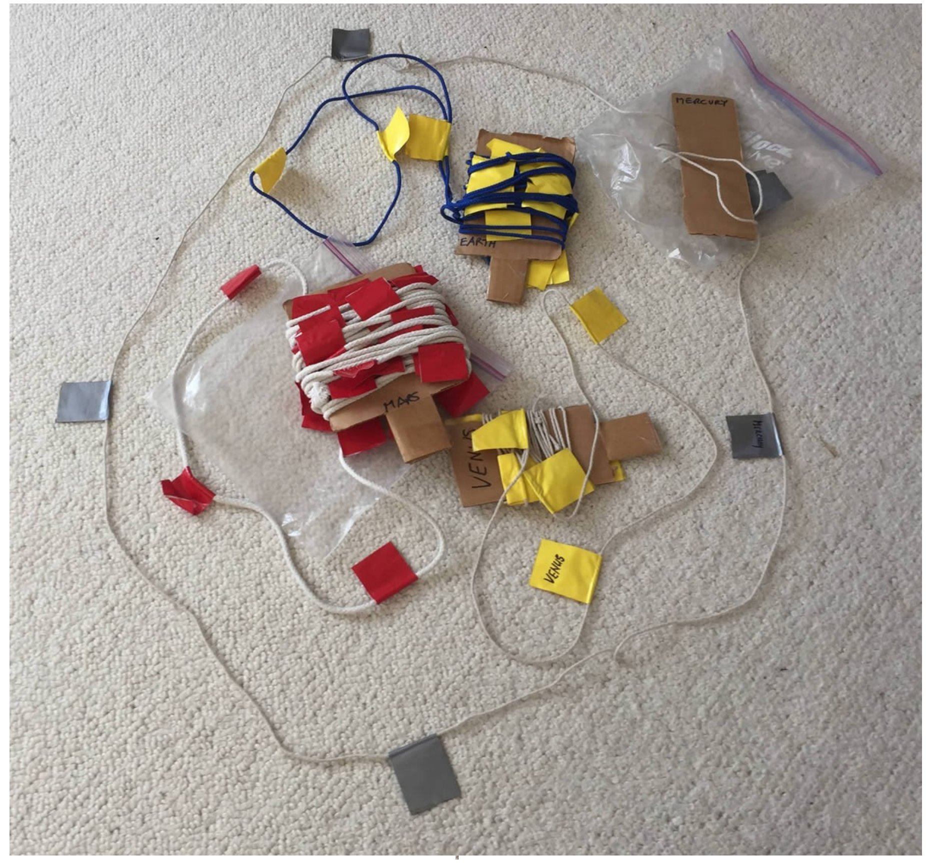


Photo of orbit ropes with pieces of tape attached.

GO! (In-Class Instruction Guide)

I. ENGAGE:

Ask, ***Have you ever made a model of the solar system?***
Accept student responses. Mention the difficulty of making a model with planet size & distance from Sun to the same scale.
Explain that an orrery is a scale model showing positions and motions of planets, and that the class can make a human model orrery, one-hundred billionth the size of the actual Solar System. At that scale only the 4 innermost planets would fit in the space we have.
Ask, ***What are the 4 innermost planets of our Solar System?***
The sizes of the planets' orbits will be to scale, but the scale size of the Sun would be less than 2 centimeters (hold up 1.4 cm bead) and the planets would

all be less than 1/8 of a millimeter. [Mercury – 0.05 mm (1/20 mm), Venus – 0.12mm (1/8 mm), Earth – 0.13mm (1/8 mm), Mars – 0.07mm (1/16 mm)]

II. EXPLORE—Set up the orrery.

1. Position the Sun.

Have the class stand in a circle. Ask for a volunteer to be the Sun. The Sun stands in the center of the circle.

2. Set up and model Mercury's orbit.

Select 6 students to mark Mercury's orbit. Have them use the Mercury circumference rope to form a circle around the Sun on the ground. Explain that this is the path of Mercury in its orbit on our orrery.

Ask for a volunteer to model Mercury in its orbit. Explain that just as the model has a distance scale, it also has a time scale: each tape mark is about 2 Earth weeks (that's one "fortnight" in Old English units).
Have the class clap their hands, approximately one clap per second and chanting "two weeks" with each clap, while the Mercury student volunteer steps from mark to mark around the Sun in a counterclockwise orbit, one step per clap. Assign at least two students to keep count of the number of claps, instead of joining in the "two weeks" chanting. If desired, start slowly, clapping about once every 2 seconds, then pick up the pace.
Ask, ***How many weeks does Mercury take to make a complete orbit around the Sun?*** [6 paces = 12 Earth weeks.]

Verify that with the clap-counter volunteers. Hand out Human Orrery Observation Sheet to each student and have them record the number of paces and number of week in the Mercury row of the table.

3. Set up Venus's Orbit.

Choose a different student volunteer to represent the Sun at the center of the circle and have 10 or more student volunteers form a circle that is larger than Mercury's orbit make the Venus circumference orbit rope into a circle on the floor around the Mercury rope.

4. Compare Mercury and Venus.

Have the students to compare the orbits and ask,
If Mercury and Venus were racing around the Sun, who do you think would win the race? [Mercury, because Venus's marks are closer together than Mercury's.]
Choose two student volunteers to represent Mercury and Venus. Explain that both planets must move according to the same time scale—2-week steps. Have the class and clap hands and chant to mark every "two weeks" and with each clap, Mercury and Venus move one step to the next mark, counterclockwise around the Sun. As before, assign at least 2 students to be clap-counters. After a dozen or so claps, stop and ask,
Was your guess about who would win the race correct? [It was Mercury.]
Ask, ***How many weeks does it take Venus to make a full orbit around the Sun using this time scale?*** [16 steps x 2 weeks/step = 32 weeks]

Explain that “year length” means time for one complete orbit around the Sun, but for some classes, "orbital period" is a better term to use to avoid confusion about the idea that 1 year = 365 days.]

5. Set up Earth’s Orbit and Mars’s Orbit.

Create the orbit of Earth and Mars like you did the orbit of Venus, but with 15 or more student volunteers forming a larger circle and stretching out the Earth circumference orbit rope. Then even more students can stretch out the Mars circumference orbit rope. Ask,

What do you notice about the spacing of the 2-week tape markers on the Earth orbit compared with those on the Venus orbit? [Earth orbit markers are closer together than those in the Venus orbit.]

Will Earth will move slower or faster than Venus? [Slower.]

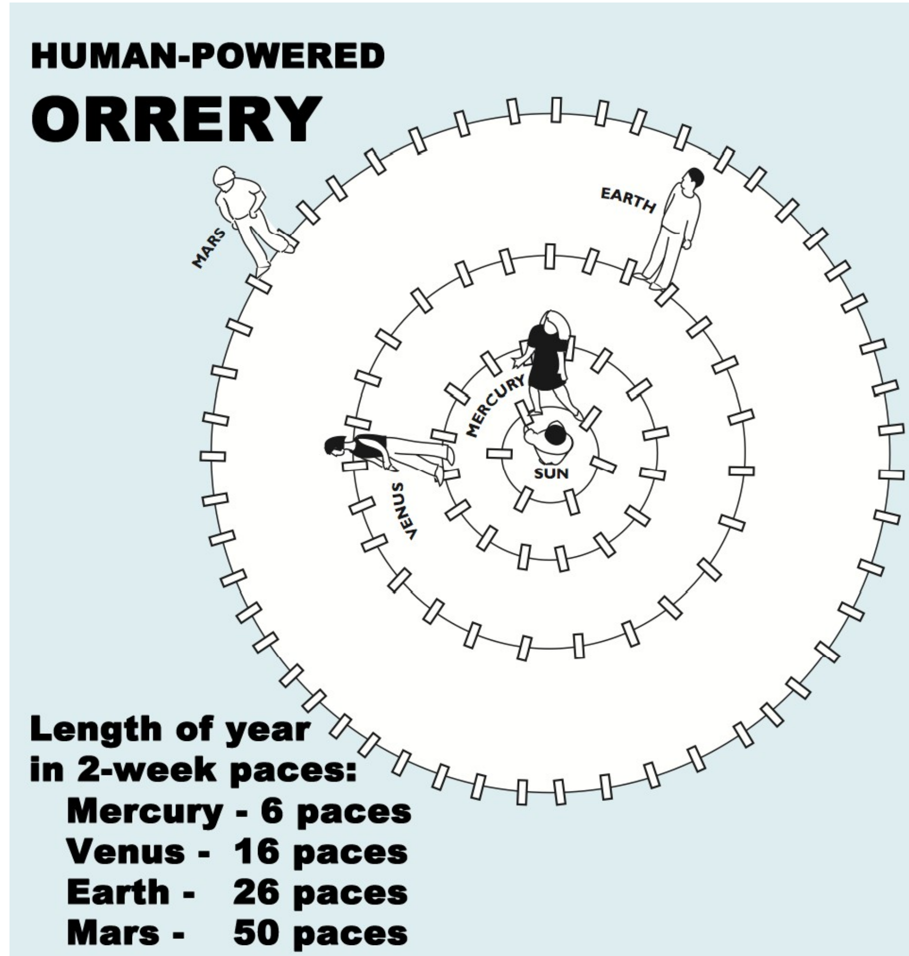
Will Mars move slower or faster than Earth? [Slower—the Mars orbit markers are even closer together than those on Earth’s orbit.]

6. Run the Human Powered Orrery for all four planets.

Run the Human Orrery now with student volunteers for the Sun and all four planets. Have the 4 student planet volunteers line up as if they are about to begin a race, with one student on each planetary orbit. Tell the class that this is an unusual planetary alignment.

Ask, ***If the planets were racing to complete their orbits, which planet would you want to be to win this race?*** [Mercury.]

Have everyone clap together chanting “two weeks” with each clap. Stop after 26 claps when Earth has made one full orbit around the Sun. Ask the class how many weeks have passed. [52 weeks, or 1 year.] Ask students to describe the progress of the other planets and how much time has gone by for them. Run the orrery with new students to make sure that everyone participates. Solicit comments and observations from students as they observe the model in action.



III. Explain: What Does the Orrery Show Us?

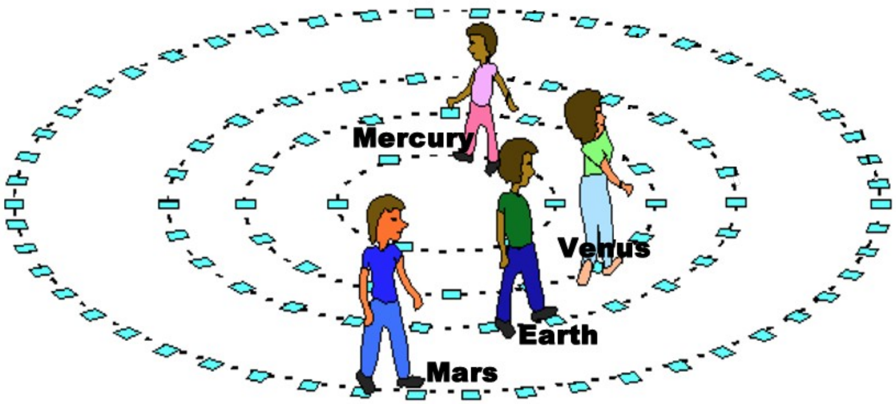
Have students discuss with a partner the “Orrery Questions” on the bottom half of the Observation Sheet and then write their answers to the questions. Then lead a class discussion if there are any remaining uncertainties about the answers:

a. “Is it is the length of the planet’s orbit, or the planet’s speed that makes the difference in the time for one complete orbit?” [Both.]
b. “What does the term “year length” mean?” [Time for one complete orbit around the Sun.] “Which planet has the shortest year length?” [Mercury] “Which planet has the longest year length?” [Mars]
c. “Is there a relationship between the distance from the Sun and their year lengths?” [The farther from the Sun, the longer the year length.] “Why do

planets closer to the Sun have smaller year lengths?" [Shorter orbits and faster speeds.]

d. "How would the movements of the planets appear to someone standing in the position of the Sun?" [The planets appear to move in an organized and orderly manner around the Sun. The viewer sees a consistent pattern in the motion of the planets.]

e. "How do the movements of the planets appear to someone on the Earth?" [Since Earth is not in the center of the Solar System and is in motion, the movements of the planets seem complex to an observer on Earth. The planets appear to wander about in different directions and speeds.] Explain that the word planet comes from an ancient Greek word that means "wanderer."



IV. Evaluate: How Good is the Model?

Conclude by having teams list the accuracies and inaccuracies of the orrery.

Some things the model showed accurately:

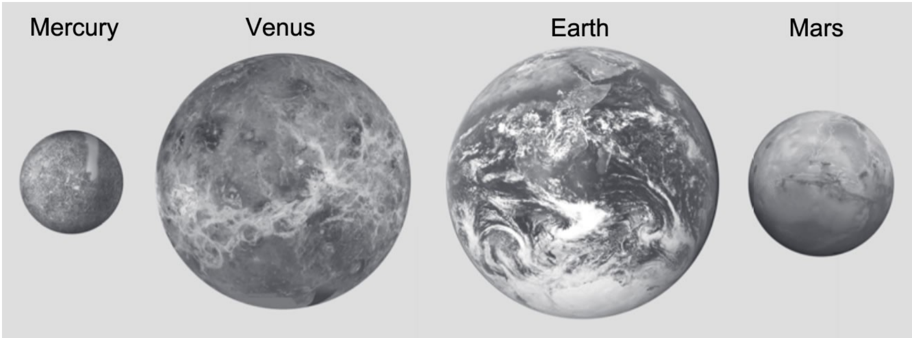
- All of the planets orbit the Sun in the same direction.
- All of the planets's orbits are in the same plane.
- The orbits are all close to circular.
- The inner planets move faster & have shorter orbits than the outer planets.

Some things the model showed inaccurately:

- The sizes of the planets are not to scale.
- The planets do not spin.

Optional: have students to make predictions about the year lengths and speeds of the outer planets. Then discuss this chart.

Planet	Earth Weeks	Earth Years	Orbital Speed (km/s)
Mercury	12	0.2	48
Venus	32	0.6	35
Earth	52	1	30
Mars	96	1.9	24
Jupiter	308	12	13
Saturn	766	29	10
Uranus	2,184	84	7
Neptune	4,290	165	5



This activity is based on Space Science Sequence (http://www.lhsgems.org/SpaceSciSeq.htm) Grades 6–8, Unit 3, session 10 (http://kepler.nasa.gov/files/mws/HumanOrrerySSSmsGEMS.pdf) from Great Explorations in Math and Science (GEMS; http://www.lhsgems.org/)

Human Orrery

Observation Sheet

Planet	Number of paces in a year [1 pace = 2 Earth-weeks]	Number of Earth-weeks in a year	Scale Distance from the Sun (cm)
Mercury			58
Venus			108
Earth			150
Mars			228

Orrery Questions

a. Is it is the length of the planet's orbit, or the planet's speed that makes the difference in the time for one complete orbit?

b. What does the term "year length" mean?

Which inner planet has the shortest year length? ____________________

Which planet has the longest year length? __________________________

c. Is there a relationship between the distance from the Sun and year length for a planet? Explain why.

d. How would the movements of the planets appear to someone standing in the position of the Sun?

e. "How do the movements of the planets appear to someone on the Earth?"