Comparing Planetary Orbits

This activity is a complement to *Comparing Mars & Earth Season*s on page 29 of the KA guide. It allows further exploration and analysis of planetary revolution while providing a strong link to mathematics. Seeing the orbits as circles that are subdivided into fractions provides many possibilities for using, seeing, and experiencing fractions in an astronomical context. It also links to the ST 22 worksheet and ST 23 answer sheet in KA.

Once students have completed the KA guide, it is possible to give them some memorable insight into the way in which the planets revolve. Not all students will be able to physically participate in this activity but even observing other students and participating in the questioning is quite enlightening.

> **Props:** 2 Ropes with planet name tags. The exact process for making these is relatively quick, inexpensive and is described below.

To do this activity, several props are necessary. You will need to create 2 ropes that have the distances marked off representing the orbits of the planets out to Jupiter. This is all that is really necessary as the planets farther out than Jupiter orbit so slowly that they appear to move very little even over a 10 year (Earth time) period. Saturn is included in case you have more rope and are doing this activity outside. It is a very good extension since it is so far away and moves very slowly.

The rope can most easily be marked by using the planet distances in Astronomical Units (AU). One AU is the average Earth-Sun distance of 93 million miles. While the following table can be used to create a rope of any length we suggest starting with one that has worked well for us. Hey, we'll even take you through the math! For added clarity, please see the diagram at the end of this activity.

Assuming you can easily buy a 100 ft. rope, that's what we'll use. Take the 100 ft. rope, fold it in half and cut it so that you have two 50 ft. sections. Take each 50 ft. section and fold it in half. At the center, mark the rope with masking tape by wrapping it around the rope several times. Label this SOL for the Sun. Next, use the table below to tell you how far from the sun (in each direction) to mark the rope with tape for each of the planets. If you elect to use the distances to Saturn, make the two ropes 100 ft. long initially. Distances given below are the Sun-planet distances in AU and in feet from the center of the rope.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn
Distance from the Sun in AU	0.4	0.7	1	1.5	5	10
Rope Distance	2′	3′9″	5′	7′ 6″	25′	50′

Comparing Planet Orbits allows students to explore not only the comparative fraction of time that planets take to go around the Sun, it also gives them a basis for comparison between all planets. Other factors that can be introduced include the proper direction of revolution length of a year, seasons and the length of time necessary for seasonal change.

The table below is based on 1 Earth revolution/orbit = 1 year. All other orbits are fractions or multiples of this and have been approximated to provide meaningful fractions. (e.g. for each orbit of the Earth, Mercury makes about 4 orbits and Venus about 1.5.) The planets outside Earth's orbit will only revolve part of the way around the Sun for each Earth orbit; Jupiter only gets 1/12 of the way around the Sun and Saturn, 1/30. A complete and accurate list of planetary information can be found at www.clarkplanetarium.org under the Education link. Click on Solar System Fact Sheet to download!

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Length of Year	4	1 1/2	1	1/2	1/12	1/30	1/80	1/160	1/250

Comparing Revolutions

1. Set up the KA circle as in *The Astronomical Meaning of Day and Night*. Include the rope with marked planet positions and the large planet name tags as described above. As you do this activity, you may wish use fractions that have the same denominator for each part of the activity or you may want to make the students mentally convert to give them practice. This will become more clear as you read on.
2. Gather students around the outside of the circle.
3. Ask students: "How long does it take for Earth to revolve around the Sun?" [1 year or 365 ¼ days.]
4. Ask: "What would that look like in our model? Does anyone want to demonstrate that?" [Have student go to the Earth tag and complete 1 orbit.]
5. Ask: "Mercury is the fastest planet. How long does it take to revolve once?" [about 88 days] "Since it only takes 88 days to orbit once, about how many times will it revolve for each time Earth revolves?" [88 is ~ 90 so 360/90 = 36/9 = 4/1 = 4 times]
6. Solicit another volunteer to be Mercury. Have Mercury and Earth start out next to each other on the same rope. Tell all students: "Now, we will see what it looks like when both planets revolve at the same time." Ask all students: "How far will Mercury travel if we send Earth ¼ of the way around its orbit?" [Mercury will make 1 revolution while the earth only travels ¼ revolution.] Students should represent this on the model.
7. Ask similar questions while Mercury makes orbits number 2, 3, and 4. [By the second orbit Earth should be ½ way around in its orbit. By the time 4 orbits are completed, the two planets should be back where they started.]
8. Tell Mercury: "Come out of the circle so we can explore Venus' orbit." Tell students: "It takes 1.5 years for Venus to revolve around the Sun. Does anyone want to be Venus?"

9. After selecting a student, start Venus and Earth next to each other. Ask students, “If Venus orbits 1 1/2 times for each Earth orbit and we have Earth go through ½ of a revolution, where will Venus be at the end of this time?” [Earth will experience ½ an orbit while Venus will go ¾ of the way around the Sun.] Tell Earth and Venus: “Please demonstrate what you think will happen.” [Make sure they get to the right place.]
10. Ask students: “Where will Venus end up after Earth completes one full revolution?” [1 ½ orbits] Tell Earth and Venus: “Complete your orbits.” **Recap.** Tell students: “So, the 2 inner planets revolve in less time than the Earth. Ask students: “So, while Earth makes one revolution, how may does Mercury make? Venus? Invite Earth and Venus to come out of the circle.
11. Tell students: “Now its time to move on to the outer planets—those that orbit outside Earth’s orbit. What is the next planet in terms of distance out from the Sun?” [Mars] “Do you think it will orbit faster or slower than Earth? Does anyone know how the movement of Mars is different than the inner planets?”[Mercury and Venus are only visible in the evening or morning, whereas Mars can sometimes be seen at any time of night.]
12. Ask students: “Who would like to be Mars? Earth?” Start Mars and Earth next to each other. [With Mars you will want to do 2 revolutions, which means that Earth will have to do 4.]
13. Ask students: “Does anyone know how long it takes Mars to revolve?” [Almost 2 Earth years.] Ask students: “If it takes Mars 2 years to revolve once, how far would it get in ½ a year?” [1/4 revolution] “How far would it revolve in ¼ year?” [1/8 revolution] For this part of the demonstration, we are only going to send Earth ¼ of the way around at a time since it is now moving slower.
14. Remind students: “Remember when we all held our east and west signs to help us figure out what was visible in our sky? We’re going to use those skills for our Mars investigation.” Ask Earth: “Can you see Mars in your sky?” [Yes.] “When can you see it?” [From sunrise to sunset.]
15. (EARTH AT ¼ revolution) Command Earth: “Move ¼ of the way in your orbit.” Ask Mars: “How far do you need to revolve now?” [1/8 revolution.] Ask Earth: “Can you see Mars in your sky? [Yes.] Has the time of day when Mars is visible changed? [Not by much. Mars has moved a bit into the western sky at sunset.] As you both moved in your orbit, what direction was Mars going in your sky?” [East to west.]
16. (EARTH AT ½ revolution) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will be ½ way around while Mars is ¼.] Ask Earth: “Can you see Mars in your sky? [Yes.] Has the time of day when it is visible changed? [Yes. Mars is getting low in the west at sunset and is visible only for a short time.]
17. (EARTH AT ¾ revolution) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will be ¾ of the way around while Mars is 3/8.] Ask Earth: “Can you see Mars in your sky? [Yes.] Has the time of day when it is visible changed? [Yes. Mars is setting just after the sun and will no longer be visible after another month has passed.]

18. (EARTH AT 1 revolution) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will have completed one revolution while Mars has completed 4/8 or 1/2.] Ask Earth: “Can you see Mars in your sky? [No. It sets and rises with the Sun.]
19. (EARTH AT 1 ¼ revolution) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will be 1 1/4 of the way around while Mars is 5/8.] Ask Earth: “Can you see Mars in your sky? [Yes.] Has the time of day when it is visible changed?” [Yes. Mars is rising just before the sun.]
20. (EARTH AT 1 ½ revolution) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will be 1 ½ revolutions while Mars is 6/8 or 3/4.] Ask Earth: “Can you see Mars in your sky? [Yes.] Has the time of day when it is visible changed? [Yes. Now rising about midnight.] As you both moved in your orbit, what direction was Mars going in your sky?” [East to west.]
21. (EARTH AT 1 ¾ revolution) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will be 1 ¾ revolutions while Mars is 7/8.] Ask Earth: “Can you see Mars in your sky? [Yes.] Has the time of day when it is visible changed? [Yes. Now rising about 9 p.m.] “As you both moved in your orbit, what direction was Mars going in your sky?” [We are now even with Mars and would see it stand still in our sky for several days as we pass it.]
22. (EARTH AT 2 revolutions) Command Earth and Mars: “Revolve for ¼ of a year.” [Earth will be 2 revolutions while Mars is 1.] Ask Earth: “Can you see Mars in your sky? [Yes. It’s just like the start position.] Has the time of day when it is visible changed? [Yes. Now visible from sunset to sunrise.]
23. **Recap.** Ask students: “About how old would you be if you lived on Mars? [½ of their current age.] “How often is Mars visible in our skies?” [Quite often.] How long does it take to from the time when Mars is visible all night until it isn’t visible at all? [Almost a year.] So, while Earth makes one revolution, how may does Mercury make? Venus? Invite Earth and Mars to come out of the circle.
24. Tell students: “Let’s get everything into motion at once.” Select new students to model all of the planets and include Jupiter this time. Again, compare all the orbits to Earth’s.
25. Tell students: “It takes Jupiter 12 years to revolve once. Therefore, Jupiter will only go around 1/12 of an orbit for each revolution of Earth.” Ask students: “So, how far will Jupiter revolve for every ¼ Earth year?” [That means that it will only go ¼ of 1/12 or 1/48 of an orbit for each quarter of an Earth year. That’s not much!]
26. Ask students: “Given these numbers, where should Jupiter end up after the whole year has passed? [1/12th of the way around. Make sure the student modeling Jupiter picks an ending point for his journey that is less than 1/8 of the way around (as demonstrated before by the first move of Mars)].
27. Tell students: “Let’s go! Everyone advance the appropriate amount for ¼ of an Earth orbit. [Mercury = 1 rev., Venus = just over 1/3, Earth = ¼, Mars = 1/8 and Jupiter 1/48.]
28. Tell students: “Revolve for ¼ Earth year.” [Mercury = 2 rev., Venus = just over 2/3, Earth = 1/2, Mars = 1/4 and Jupiter 2/48 = 1/24.]

29. Tell students: “Revolve for ¼ Earth year.” [Mercury = 3 rev., Venus = about 1 1/8, Earth = 3/4, Mars = 3/8 and Jupiter 3/48.]
30. Tell students: “Revolve for ¼ Earth year.” [Mercury = 4 rev., Venus = 1 ½, Earth = 4/4 = 1, Mars = 4/8 = ½ and Jupiter 4/48 = 1/12. This means that Jupiter is in a different sign of the zodiac every year!]
31. Tell students: “If we were to include Saturn, Saturn would move about 1/3 as fast as Jupiter! That’s why it takes it about 30 years to make one revolution.
32. Ask Students: “How long does it take for all the planets to line up on the same side of the sun? (Like the pictures you always see in books?) [Probably NEVER but if we assume that close counts, A VERY long time.]

While the planets may never technically get lined up, we can use the rough numbers in given in our exercise to get a feel for how the planets actually move. The worksheet will give students practice thinking about what they have done in today’s activity.