Physics 10293 Lab #6:
Mercury

Introduction

Today we will explore the motions in the sky of the innermost planet in our solar system: Mercury. Both Mercury and Venus were easily visible to the naked eye near sunrise and sunset, and their distinctive patterns of motion were studied closely by many cultures.

Step 1

Start by opening the Skyguide tab on the sidebar, then select the top option, "Student Exercises".

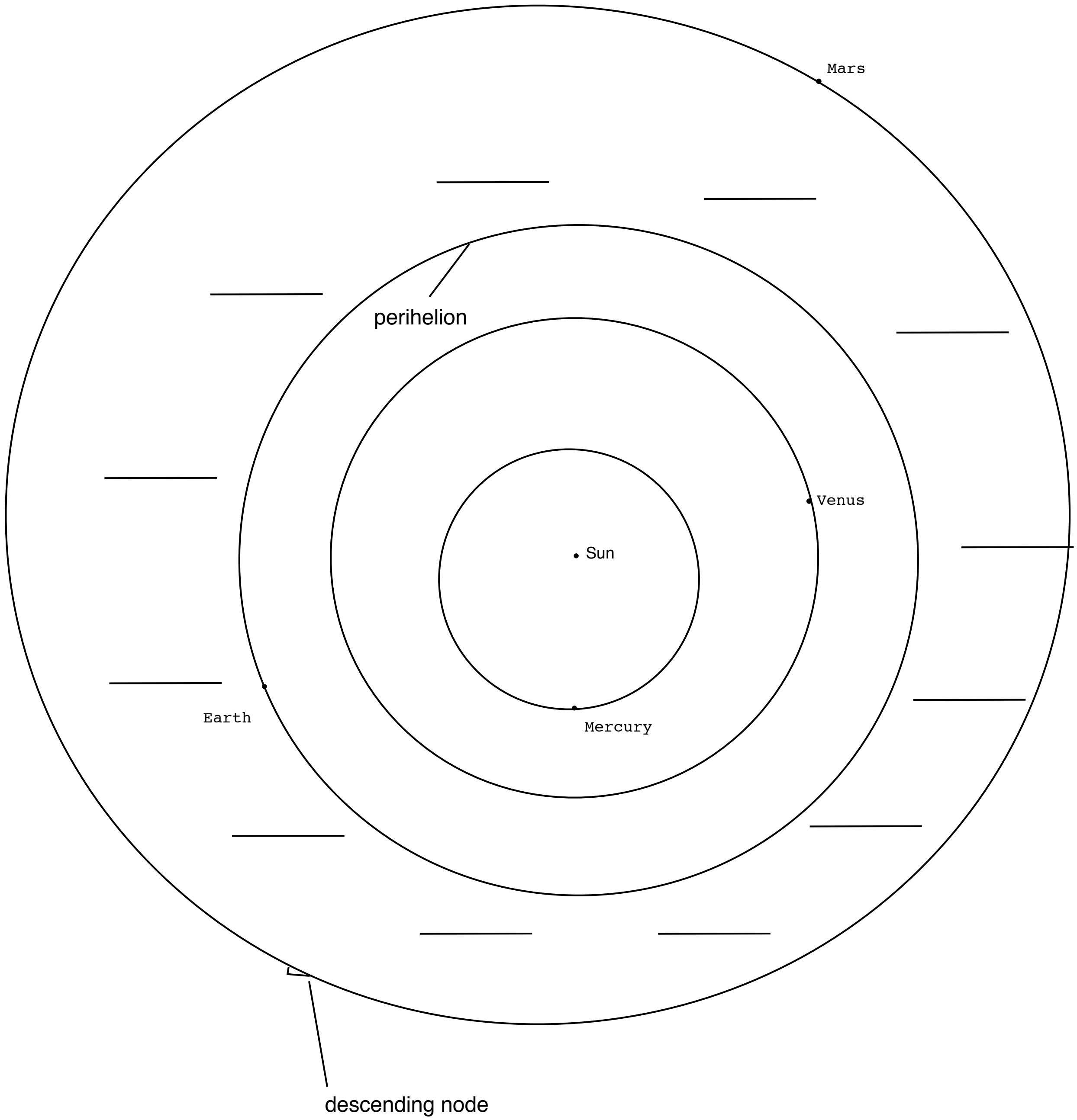
Select "C: The Planets". This will open a list of exercises.

Open **Exercise C1:** The Inner Planets of the Solar System and from here, Part 1: Orbits of inner planets. You may want to zoom in a little bit here so that the features are clearer.

Time

On your diagram on the following page, the figure on your screen has been reproduced as a negative and a few features labeled. Notice on the diagram twelve blanks surrounding Earth's orbit. By watching the motion of the planets on your screen, write in three letter abbreviations in each blank corresponding to the month when Earth is in that position in its orbit around the Sun.

Label the months in the diagram below.



Conjunctions

Next, notice the locations of Mercury and Venus in the diagram above. The location of Venus is on the far side of the Sun, almost exactly opposite of the Earth. We call this position “superior conjunction”. Conjunction means “joining”, so this is a time when the Sun and Venus are apparently joined on the sky. When a planet is between the Earth and Sun, we call this position “inferior conjunction.” During conjunctions, a planet is not easily visible since it is so close to the Sun in our sky.

Perihelion

On your screen, a small tick mark perpendicular to a planet’s orbital path denotes the perihelion for each planetary orbit (shown for Earth on the diagram on the previous page). Since all planetary orbits are elliptical, there will be a point in the orbit at which the planet is closest to the Sun (perihelion) and furthest from the Sun (aphelion).

Nodes

Next, notice on your screen the small half-arrows attached to each orbital path. Like the Earth’s moon, the orbital planes of the planets do not exactly match up with the Earth’s average orbital plane, also known as the plane of the Ecliptic.

There are two places where the planets cross through the Ecliptic plane: the ascending node and the descending node. The descending node is marked with a hollow half-arrow for each planet (this has been reproduced on the diagram on the previous page for Earth’s orbit). This is where the planet is plunging down through the plane of the Ecliptic. On the opposite side of the planet’s orbit (on the screen but not shown on paper) is the solid half-arrow which marks the ascending node.

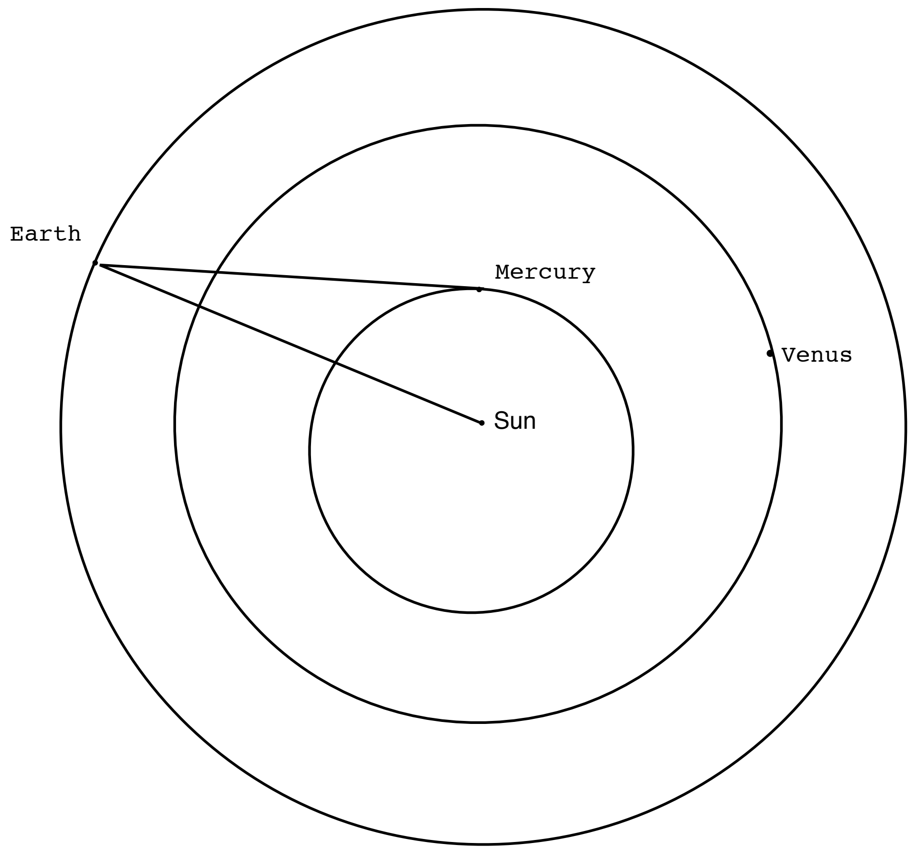
When an inner planet moves in front of the Sun like our Moon occasionally does, we do not call it an eclipse. Instead, we call it a transit. Planetary transits can occur when the planet is at a node at the same time it is lined up with the Earth and the Sun. Below, for the planet Mercury, write down which months of the year it is possible to see a transit of this planet from the Earth. This answer doesn’t depend on the year.

Mercury transit is possible in which two months?

______________ and ________________.

Step 2

Below, Figure 1 shows Mercury at its perihelion point. A line has been drawn from Earth's orbit to Mercury's perihelion point.



Elongations

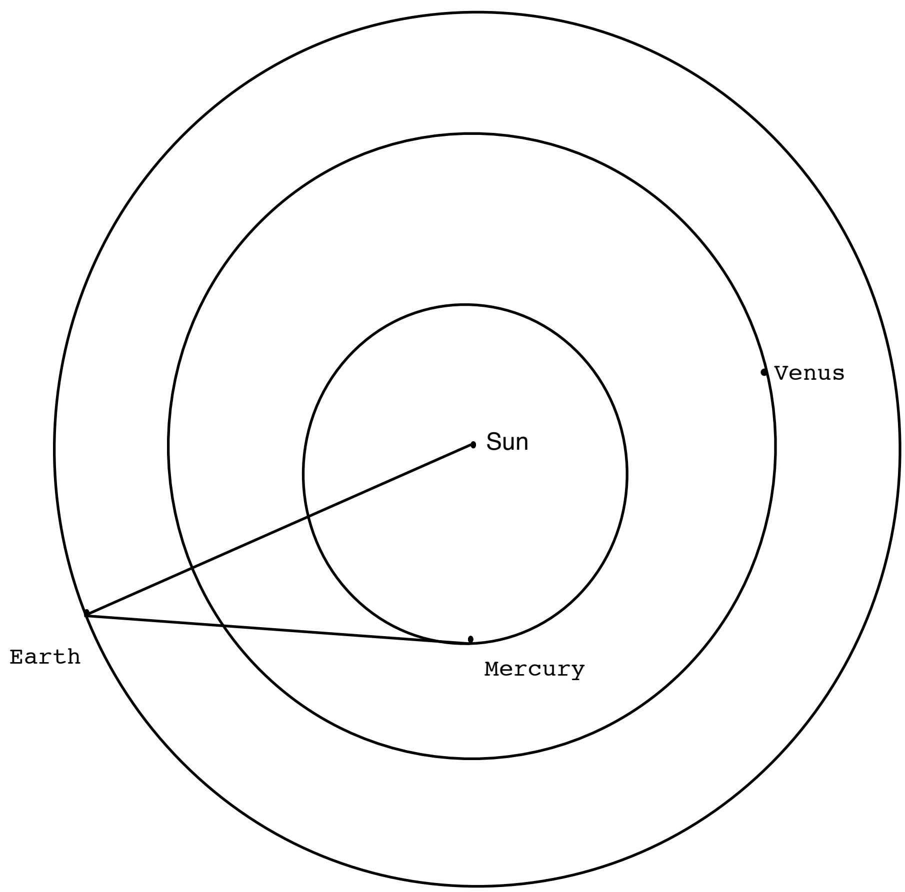
When the Earth is here, we see Mercury at one of its greatest elongations, or furthest angular distances from the Sun. This is possible four times during Earth's orbit, but only one example is shown in Figure 1.

When Mercury is at perihelion, its greatest elongation is 18°. That means the angular distance in the sky between Mercury and the Sun is 18°. That's about the same angular distance as exists between Rigel and Betelgeuse (the two brightest stars) in the constellation Orion. That's also about the same as the angular length of the handle of the Big Dipper.

Below, a diagram shows Mercury at aphelion, its furthest distance from the Sun. This is the second of four possible orientations where Mercury can be seen at a maximum elongation. Again, a line has been drawn from Mercury's aphelion to the Earth's orbit, showing where the Earth is located when Mercury experiences its greatest elongation at aphelion, which is 28°. That's about the distance from the tip of the handle to the tip of the bowl of the Big Dipper.

From Earth's perspective, as Mercury orbits the Sun, it can be seen either to the left or the right of the Sun periodically, and the maximum angle from the Sun along this apparent path is always somewhere between about 18° and 28°. Obviously, the most favorable time for naked eye observations of Mercury occurs when its angular distance from the Sun is maximized.

Notice that if a planet is at maximum elongation, if you draw a line from the planet to Earth, that line will make a right angle with a line from the planet to the Sun.



Monitor the motion of the Earth and Mercury, changing the date when necessary, and answer the associated questions below.

Set the date in the simulation for January 1 of next year.

What is the first day after this date that...

Mercury will be at inferior conjunction? ______________________

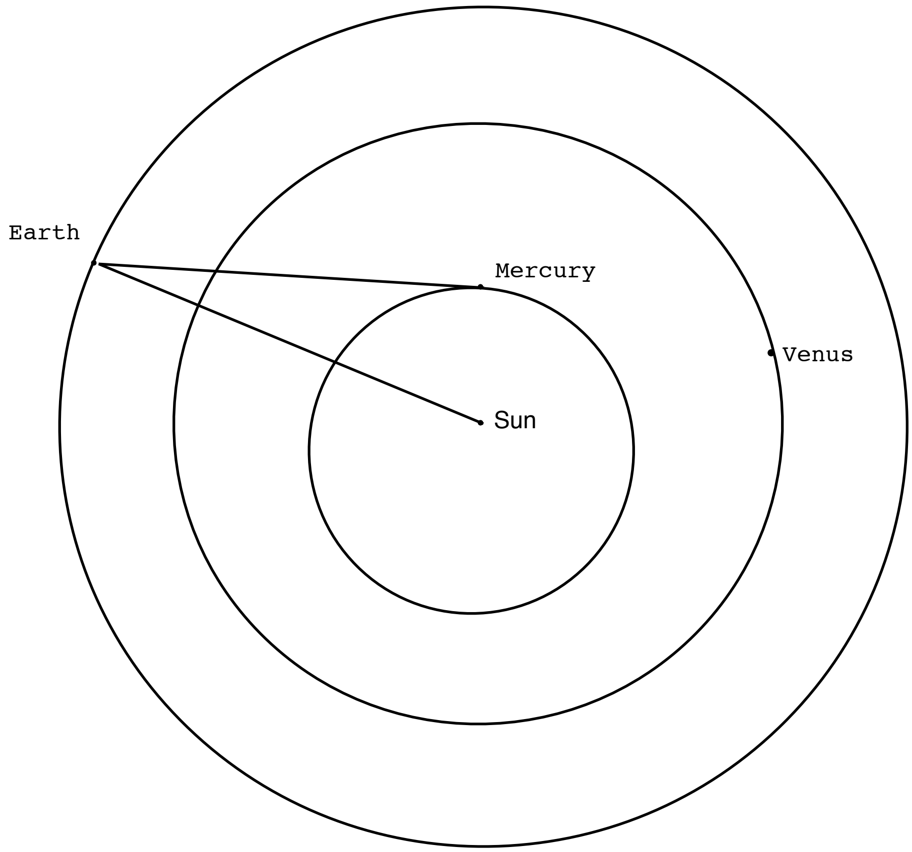
Mercury will be at maximum elongation? _______________________

Mercury will be at superior conjunction? _______________________

What is time interval (in days) between consecutive inferior conjunctions?
This is Mercury's synodic period. _________________________

What is the time interval (in days) of Mercury's orbit? For example, how long is the time interval starting from perihelion to its next appearance at perihelion? This is the sidereal period. ______________________

On the diagram below, show all four possible Earth-Mercury configurations that result in elongations at either perihelion (18°) or aphelion (28°). Ask your TA for help if necessary, but it is better if you try (in pencil) first to see if you understand.



Next, think about the direction of orbital motion and rotation (both counterclockwise) for the Earth. For each of your four configurations, label whether Mercury would appear in the morning (before sunrise) or in the evening (after sunset). To get you started, the first configuration shown would be "evening".

Finally, use the mouse to drag on the screen so that it rotates downward. This has the effect of rotating your view of the planetary orbits until you get an edge-on view. Notice the orbits are all nearly coplanar. Mercury's orbit (red) is tilted with respect to Earth's orbit (green) by an angle of 5°. That's coincidentally the same angle our Moon's orbit is tilted compared to the Ecliptic!

Step 3

Now we will study the apparent motion of Mercury in the sky as seen from the Earth. Although Mercury's maximum possible elongation of 28 degrees seems like a pretty big angle on the sky, Mercury can be difficult to see.

First of all, it is only visible to the naked eye when the sun is just below the horizon (before sunrise or after sunset), and so the sky in that direction is still fairly bright. The longer you wait, the darker the sky gets, but also the lower in the sky Mercury goes so that atmospheric effects (which make Mercury dimmer and redder) increase.

Also, just because the angular separation of Mercury and the Sun is as much as 28°, that does not mean Mercury is 28° above the horizon at sunrise or sunset! To help you understand why, we need to set up Starry Night in a certain way.

- Hit the "Home" button near the center of the top bar, just beneath the "Viewing Location" box.

- Close the SkyGuide tab.

- Open the Options tab.

- Under "Guides," select "Ecliptic Guides", then check "The Ecliptic".

- Under "Local View", uncheck "Daylight".

- Under "Solar System", uncheck "Asteroids" and "Comets"

- Under "Solar System", check the Labels box for Planets-Moons

- Under "Solar System" click on the actual words "Planets-Moons" to open up an options box. At the bottom of this box, check "Label only planets bright than" and move the slider to a magnitude of about 4.

- Under "Solar System", uncheck "Satellites" and "Space Missions"

- Now drag the sky around until you are looking at the <u>Western</u> horizon.

- Use the "Options" menu at the top of your screen. On this menu, scroll down to "Other Options" and from that menu, select the top choice, "Local Horizon..."

- On the "Local Horizon..." screen, select "Flat" horizon.

- Set the time to sunset on January 1 of next year.

At this point, you may want to ask your TA to double-check your screen to ensure your settings are all correct.

The green line that passes through the Sun and has monthly labels on it is the ecliptic. It serves as the apparent annual path of the Sun in the sky. On your screen, the Sun is in the "Jan" part of the ecliptic. As the year progresses, it will move to the "Feb" part, the "Mar" part, etc.

But it also marks out the plane of Earth's orbit. Remember that Mercury's orbit is tilted with respect to Earth's orbital plane by 5° (we saw that in the edge-on view of planetary orbits). That means Mercury will always be found close to the ecliptic.

Now pay attention to the <u>angle</u> the ecliptic makes with the horizon. Set the time flow rate to "1 day" and run time forward, watching the angle the ecliptic makes with the horizon throughout the year. <u>In the space below, note during which month the ecliptic makes the steepest (largest) angle with the horizon and which month the ecliptic makes the shallowest (smallest) angle with the horizon</u>.

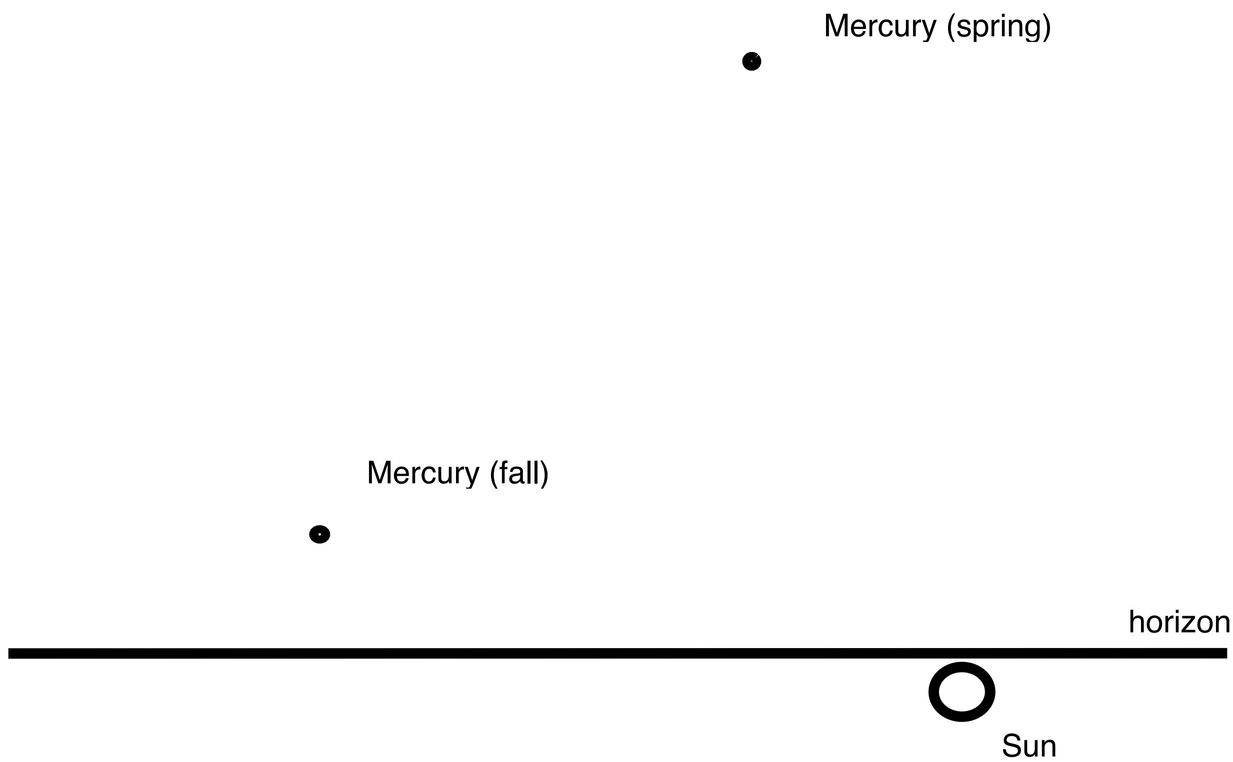
During which month does the ecliptic make its steepest angle with the horizon?

____

During which month does the ecliptic make its shallowest angle with the horizon?

____

The best time to see Mercury will be during a month when the ecliptic makes a steep angle with the horizon, as shown in below in Figure 3.



<u>Figure 3</u>

During Spring, when the ecliptic makes a steep angle with the horizon, it is possible for Mercury to appear very high in the Western sky at sunset. During Fall, when the ecliptic makes a shallow angle with the horizon, even if Mercury is at a large angular distance from the Sun, it won't be very high above the horizon and so not very easy to see.

Thus, the best time to view Mercury is during the Spring.

Now a few more quick steps so we can see another interesting effect.

- First, under the “Options” menu on the top bar, select “Orbit/Path Options...”.
- On this screen, check the box near the top marked “Use infinite path length”
- There is a slider below the “Show circular markers” box. Slide this to the smallest value possible (1).
- Uncheck the box near the middle that says “Show date/time”. Then close the box.
- Set the time to sunset on March 21 of next year.
- Make sure the time flow rate is set to “1 day”

Now run time forward. As soon as the planet Mercury is visible above the horizon, stop the time flow and right click on Mercury. This brings up a long menu, and about 2/3 of the way down, select “Local Path”.

This will show Mercury’s day-to-day path across the sky, as though you were observing and carefully marking its position on a star chart every day at sunset, just like the ancient Mayans, Egyptians or Babylonians once did. You will notice Mercury’s path across the sky has two very distinct shapes, a shorter path and a longer path. Stop the simulation after Mercury has completed each of the two paths once.

<u>Sketch the shapes of these two paths on the next page</u>.

Sketch the shorter path of Mercury across the sky after sunset in the space below.

horizon

Sketch the longer path of Mercury across the sky after sunset in the space below.

horizon

After you are finished, you may want to see the simulation run for a while so that you can see the patterns of these two paths over the course of many years.