Planetary Orbits

Your Name: **Date:**

The Zodiac - The Solar System is basically flat. All the planets (including the Earth) orbit the Sun in roughly the same plane. From the Earth, the "planets" are always found in the sky somewhere along a circular band called the Zodiac. In the center of the Zodiac is the Ecliptic, the line along which the Sun appears to move among the stars. Because the Solar System is so flat and the planets are always somewhere along the circular path of the zodiac, describing planetary motion is relatively simple, as we only have to follow motions along the zodiac. The motions perpendicular to the ecliptic are small and can often be neglected. Thus the models of Ptolemy, Copernicus, and others can be drawn on flat sheets of paper and do not require three dimensional (3-D space) models.

Planetary Configurations - The planets in the solar system are separated into two groups. Inferior planets, Mercury and Venus, are those which orbit closer to the Sun than the Earth. Superior planets, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto, have orbits farther from the Sun. As a planet orbits the Sun, there are many arrangements possible between the Earth, the planet, and the Sun. Astronomers have identified some particular geometric arrangements of a planet's position relative to the Sun and Earth.

Conjunction is when two objects are seen close to each other in the sky. When either Mercury or Venus is along a line between the Earth and the Sun, the planet is said to be in inferior conjunction. When an inferior planet is on the opposing side of the Sun with respect to the Earth, the planet is in superior conjunction. Inferior and superior conjunctions occur only for inferior planets. Since inferior planets are in close proximity to the Sun during conjunctions, for Earth observers the planet is usually lost in the glare of bright sunlight. Occasionally, an event known as a transit occurs. An observer on Earth, with proper viewing precautions taken for the bright sunlight, will see the inferior planet pass across the face of the Sun. The precise alignment of the planet's orbital

plane and the short duration of the inferior conjunction required for a transit event make this a rare occurrence.

The angular distance between a planet and the Sun, as viewed from Earth, is called the elongation angle. Since the inferior planets orbit closer to the Sun, Earth observers always see these planets close to the Sun's position in the sky. **Greatest elongation** is the maximum angular distance between the two bodies. During greatest elongation an observer has the longest time to view Venus or Mercury without interference from sunlight. Greatest eastern elongation is when a planet is the furthest east from the Sun. At that time, after the Sun sets in the west, the planet is observed to be near the western horizon as an "evening star". Conversely, at greatest western elongation, a planet is farthest west of the Sun and is thus a "morning star" in the eastern sky shortly before sunrise.

Conjunction for a superior planet is when the planet and the Sun appear together in the sky, so that the Earth, Sun, and planet are aligned. Since superior planets orbit outside the Earth's orbit, they have no inferior conjunctions.

Opposition is when a superior planet is found opposite the Sun in the Earth's sky. At opposition, the planet crosses the observer's meridian at midnight, and the Earth is between the Sun and planet. Opposition provides an observer with the maximum amount of planet viewing time with the Sun set. Quadrature is when the direction to a superior planet is perpendicular to the Earth-Sun line. The superior planet, the Earth, and the Sun form a right angle with the Earth at the vertex. Both eastern and western quadratures of the superior planets occur.
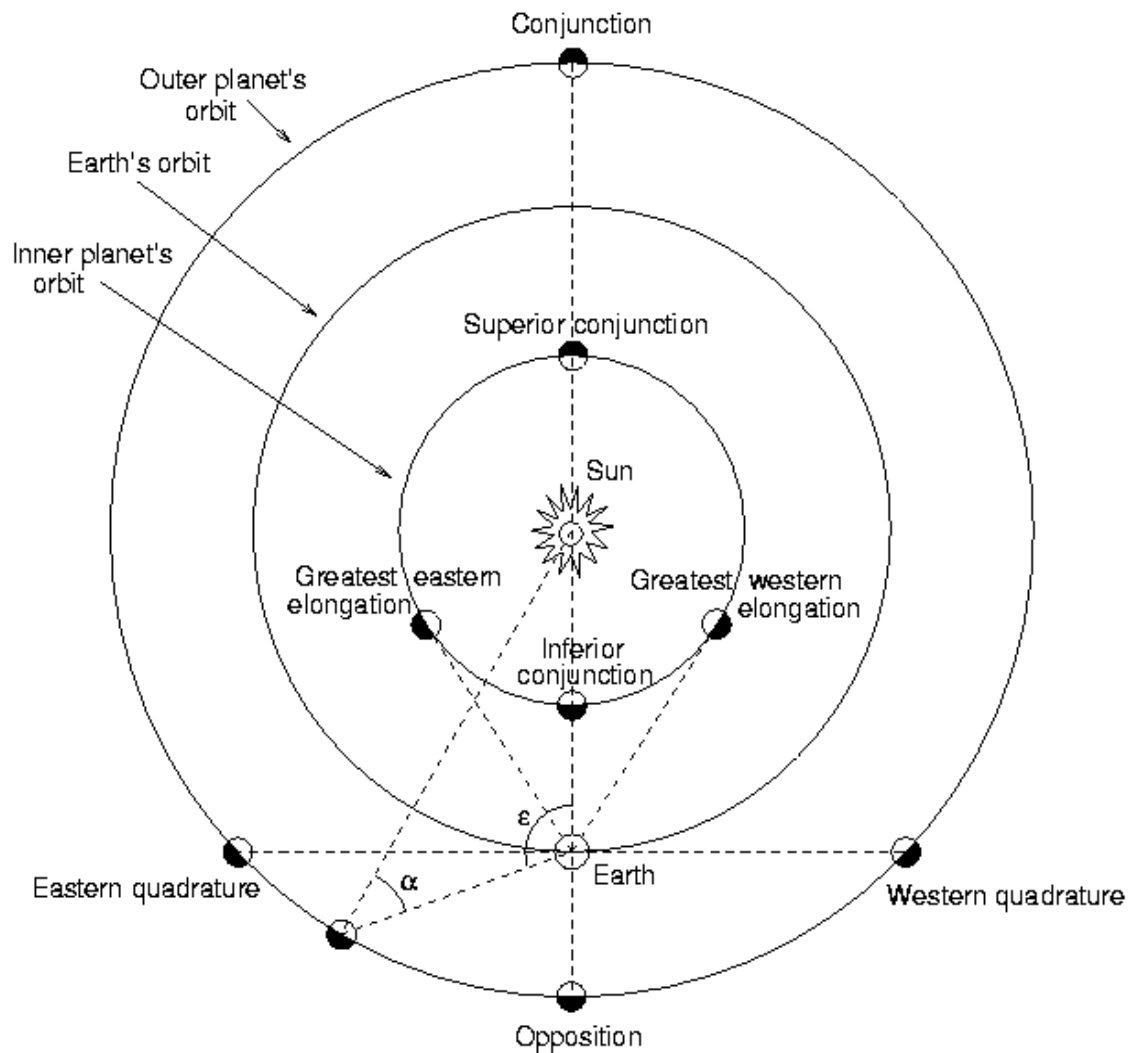
Apparent Retrograde Motion - The motion of all the planets around the zodiac is generally from west to east. This west to east motion is called prograde motion. However, all the planets (except the Sun and Moon) spend a fraction of their time moving from east to west among the stars. This is called apparent retrograde (backward) motion. Mercury and Venus spend almost half their time in apparent retrograde motion; AS101: Planetary Motions Page 3 the outer planets spend much less of their time in apparent retrograde motion. It took many years of observations for astronomers to realize that these motions repeat themselves in a regular fashion.

The synodic period is the time between similar alignments of the Earth, the planet, and

the Sun, for example, from one opposition to the next opposition. The Earth makes one orbit of the Sun in one year while Mars takes 1.88 years. If we start a clock at the next opposition of Mars, then the time it takes until the following Mars opposition will include the time needed for the Earth to orbit the Sun once and then "catch up" to Mars, which by then will have moved over halfway around the Sun in its own orbit. It takes the Earth almost another full year to catch up to Mars.

The solar day is the time between sunrises, due to the earth spinning on its axis.

The sidereal day is the time between a star rising to its next star rise. The difference between a solar day and a sidereal day is that the earth has moved in its orbit around the sun about one degree during each day, so the sun has changed positions eastward from our viewpoint. This change makes each sunrise 4 minutes later every day when you compare the time it takes a star to rise on successive days. This is the reason the constellations change season to season. The sidereal day is shorter than the solar day.

Introduction to Planetary Orbits

Go to https://mgvez.github.io/jsorrery/ which is a Solar System simulator.

On the left you can find the controls. There is a play button in the upper left that allows you to start and stop planetary motion. You can also control the animation speed with the slider at the bottom.

You can change the date as well. Which is useful to reset and play the same period of motion over again.

You can use the mouse wheel to zoom in and out.

Use the Solar System simulator to answer the following questions:

Press Play and watch the planets.

1. Which planet orbits the Sun the fastest?

Zoom in on the inner planets and reset the date to today.

Press the Play watch the Earth and Venus. You will have to reset the date and press play multiple times to go over the same time period. Remember to reset the date to today for each question.

2. When is Venus's next Inferior Conjunction?

3. When is Venus's next Greatest Western Elongation?

Now watch Earth and Mars.

4. When is the Mars' next Opposition to Earth?

5. How long is the time interval between two Mars oppositions?

6. What month does Mars reach perihelion (closest to the Sun)?

7. How were the positions of Saturn, Uranus and Neptune related on 1 March 1989?

8. Which planet is on almost exactly the opposition side of the Sun from Uranus on 1 March 1989?

9. How long does Neptune take to Orbit the Sun?

In the tool-bar on the left change the **Point of View** to the Earth, and change **Look at** to Mars.

10. Press Play and watch as mars moves through the sky. When does Mars enter and leave apparent retrograde motion?

Planets in the Night Sky

Go to https://stellarium-web.org/

Turn on the constellation lines using the toolbar at the bottom of the page. It is the first tool-button on the left.

You can adjust the time and date with the button all the way to the right at the bottom. It should show the current time when you first open the page. With the time and date window open you can also grab the slider and drag it left and right to change the time and watch the sky change.

Use Stellarium to answer the following questions.

11. What planets will be up in the night sky tonight?

12. What time does the (or did) the Moon rise **today**?

13. Look North. Describe the motion of the stars through one night (it is helpful to grab the time slider and drag it through the night time).

14. What constellation is the Sun in **today**?

15. Which planet is closest to the Sun **today**?