# Exercise 4.0

# PLANETARY ORBITS AND CONFIGURATIONS

## I. Introduction

The planets revolve around the Sun in orbits that lie nearly in the same plane. Therefore, the planets, with the exception of Pluto, are always found in the belt of the sky called the Zodiac, which is centered on the ecliptic and extends about $8^o$ on each side of it. (Pluto can be as much as $17^o$ away from the ecliptic.) Planets closer to the Sun than the Earth are classified as **Inferior planets.** Those planets farther from the Sun than the Earth are classified as **Superior Planets.** The apparent motion of a planet against the background stars depends on whether the planet is an inferior or a superior planet.

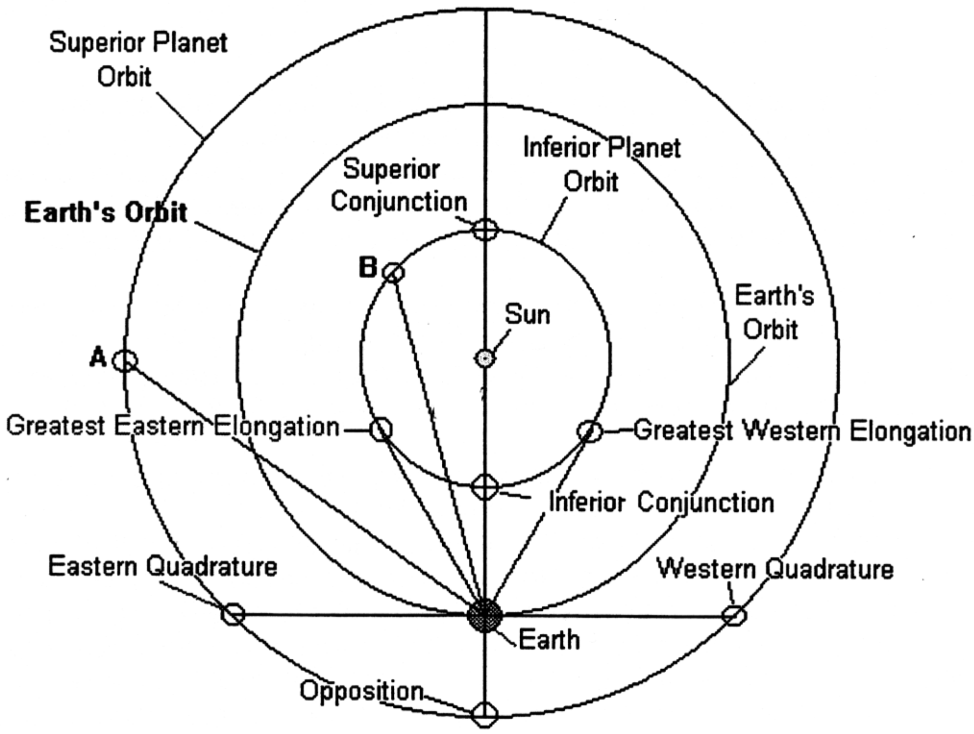
The angular separation of the Sun and a planet as seen from the Earth and measured east or west along the ecliptic is called the planet's elongation.

**Elongation is the angular distance of an object from the Sun.**

It is important to remember that **eastern elongations are negative numbers** and **western elongations are positive numbers.**

**Certain specific elongation values are given names called *Aspects* or *Configurations*.**

When two objects are in the same direction as seen from the Earth (Elongation = $0^o$), the aspect is **Conjunction.** When an object and the Sun are observed to be $90^o$ apart (Elongation = $90^o$ east or west) the object's aspect is **Eastern Quadrature** or **Western Quadrature.** When two objects are observed to be in opposite directions (Elongation = $180^o$) the aspect is **Opposition.**




The diagram on the right depicts the plane of the Earth's orbit as viewed from the north ecliptic pole. Drawn in this plane are examples of the orbits of a superior planet and an inferior planet relative to the Earth's orbit. In such a diagram, elongation is the angle between a line drawn from the Earth to the Sun and another line drawn from the Earth to the planet that is to be observed. **The vertex of the elongation angle is always at the center of the Earth, not at the Sun**. In the same diagram, westward is in the clockwise direction and eastward is counterclockwise.

For inferior planets there is a maximum angular distance the planet can be observed from the

Sun. This angle can be found by drawing a line from the center of the Earth to a point on the planet's orbit such that this line is perpendicular to a radius of the orbit. Such a line is called a tangent line. These maximum angles for an inferior planet are called **greatest eastern elongation** or **greatest western elongation.** They must always be less than $90^0$. Since an inferior planet's orbit lies within the Earth's orbit, it can never be at opposition (Elongation = $180^0$) or quadrature (Elongation = $90^0$). However, an inferior planet has two types of conjunction. One is when the planet is closest to the Earth, i.e., between the Earth and the Sun. This is called an **inferior conjunction**. The other is when the planet is on the far side of the Sun. This is called a **superior conjunction**.

The motion of a superior planet carries it through a complete range of elongations, similar to the Moon. When a superior planet is at opposition, it is closest to the Earth, and when it is at conjunction (by the geometry a superior conjunction) it is farthest from the Earth.

There is a simple relation between a planet's elongation and the approximate time it will rise, make upper transit (UT), or set. This is:

$$\mathbf{T_P = T_{\odot} - T_E}$$

The meaning of the symbols in the above equation is as follows:

$\mathbf{T_P}$ = Local Time when a planet will rise, make upper transit, etc.
$\mathbf{T_{\odot}}$ = Local Time for the corresponding solar event: rise, set, etc.
$\mathbf{T_E}$ = Planetary elongation in time units.

This equation works best when the planet and the Sun are both near the celestial equator. We can then assume that sunrise is 06:00, upper transit (UT) for the Sun is 12:00, and sunset is at 18:00. *Do not use A.M. or P.M. in the above equation; use a 24 hour clock only*. If the Sun, planet, or Moon is not near the celestial equator, the above equation may be off by more than an hour. The farther away one or both objects are from the celestial equator, the larger the error. The value of the **equation of time** (the difference between local apparent solar time and local mean solar time) is another factor that can introduce error.

## II. Tutorial

Logon to **SKYLAB2** and select program No. 6, "PLANETMATION." This program animates the motions of the planets in their orbits as seen from any distance from the Sun. When you initially call up this program, it presents a view of the solar system at a distance of 6.0 Astronomical Units (AU) from the Sun, looking towards the south ecliptic pole with an inclination of $60^o$. The planetary motions begin with today's date and time and proceed in steps of one day every 0.2 seconds (the delay time).

1. Type "D" to open the distance window and change the distance to 50 AU.
2. Change the inclination to $0^o$ by typing "V" to open the "View-angle" window.
3. As soon as the animation begins, press "H" and the orbit of Halley's Comet will be drawn showing where the comet is today.
4. Press "N" to show the names of the planets.
5. Press the space bar to halt the motion.
    a. Now look at the screen. Notice how crowded together the inner planets are on this scale. The names of the inner planets may overlap one another.
    b. Note the peculiar eccentricity of Pluto's orbit. Sometimes it is closer to the Sun than Neptune. Is this true for today's date? Remember that this is a planar projection of the orbits of the major planets onto the plane of the Earth's orbit, i.e., onto the **plane of the ecliptic.** It does not show the fact that Pluto's orbit is inclined to the ecliptic plane by $17^o$. Furthermore, the nodes of Pluto's orbit are located in the diagram at points far from where it appears Pluto could collide with Neptune. In other words, if both planets were at a point where you see the two orbits crossing, a large vertical distance would still separate them. This is because Pluto would be far out of the plane of Neptune's orbit.

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6. Now press "D" and change the distance to 10 AU.

    a. If the names of the planets are in the way for the following exercise, pressing "N"

       will remove them. You can put them back anytime you need them.
    b. Allow the animation of the planetary motions to run and watch what is happening. Now and then stop the motion and see if you can estimate the elongation of each planet. **To do this, imagine a line drawn from wherever the Earth is to the Sun and another line drawn from the Earth to the planet in question. The angle between these two lines is the planet's elongation.** The direction of the angle is west if clockwise from the Sun toward the planet or east if counterclockwise from the Sun towards the planet.

## III. Assignment

1. After you have practiced estimating elongations for several different dates, set the step size to 6 hours and the delay time to 0.8 seconds.
2. Set the date to about 7-25-1991 and the distance to 3.0 AU.
3. Set the inclination angle to zero.
    a. On some day not too long after this date in 1991, the planets Mercury and Venus will be at inferior conjunction nearly at the same time. Start the motion and keep watching these two planets until you see them line up along a line between the Sun and the Earth. Press the space bar to stop the motion when you think this event has occurred.
    b. Rerun the motion backward several days and repeat until you are sure you have determined the correct date.
4. Record this date as No. 3 on the answer sheet and obtain a printout of the screen (#1).

5. Now set the date to your birthday of the current year, the time to 21:00, the distance to 3.5 AU, and the inclination to $0^o$. Do not use the date you obtained for No. 4. Remove the names of the planets if you have them present. Obtain a printout of the screen. (This is printout #2)
6. Keep the same date and time but change only the distance to 40 AU. Make sure the orbit for Halley’s Comets is included on the chart. Now get a printout of the screen. (#3)

**Proceed to analyze printouts #2 and #3 using your manual. You will no longer need the computer.**

7. In the diagram on the first page of this exercise, use your protractor and measure the elongations for the two planetary positions marked A and B. Record these on the answer sheet as 1 and 2; don't forget the direction.

8. Carefully study printout #1 and note the relative positions of the Sun, Earth, and the planets Mercury and Venus. Draw the zero-degree elongation line on the chart and label it as $0^o$ where it meets the edge of the chart. Answer the following on the answer sheet:
    a. What is the elongation of Mercury and Venus on this date? (Answer Sheet Nos. 4 & 5)
    b. What is the name for this planetary configuration or aspect? (Answer Sheet No. 6)
    c. To what orbital class of planets do Mercury and Venus belong? (Answer Sheet No. 7)

9. On printouts #2, draw a line from the center of the Earth to the center of the Sun and extend this line to the edge of the chart. Draw an arrow head at the latter position and label it $0^o$.
10. Now draw separate lines of sight from the Earth to Mercury, Venus and Mars.

11. Use a protractor to measure the elongations of each planet and record the values on the answer sheet as No. 8. Be sure to label the angle as east or west.
12. Draw a bold arc between the two lines of sight defining each elongation angle at a position sufficiently far from the Earth so that you will be able to write the elongation and its direction along this arc. See the chart at the end of the exercise to see how this is to be done. Also draw an arrowhead at the end of the arc near the planet to indicate the sense of direction of the elongation. **Your charts should be annotated in the same way as the sample charts at the end of this exercise**.

13. Now you will need to establish the zero degree elongation line on chart #3 so that the elongations for the outer planets may be determined. This will be difficult, since at 40 AU the inner planets are located very close together and the location of the Earth will not be evident. However, we can use printout #2 to assist you in this matter.
    a. On printout #2, measure the distance between the intersection of the $0^o$ elongation line with the boundary of the chart and a convenient corner of the boundary lines.
    b. On the 40 AU chart measure this same distance from the analogous corner of the chart and make a mark.
    c. Draw a line from the center of the Sun to this mark and make an arrowhead, which is to be labeled $0^o$. You have now established the zero degree line on printout #3.
14. Now use printout #3 and repeat steps 9 through 12 for the planets Jupiter through Pluto, and Halley's Comet. Record the elongations under No. 9 on the answer sheet.

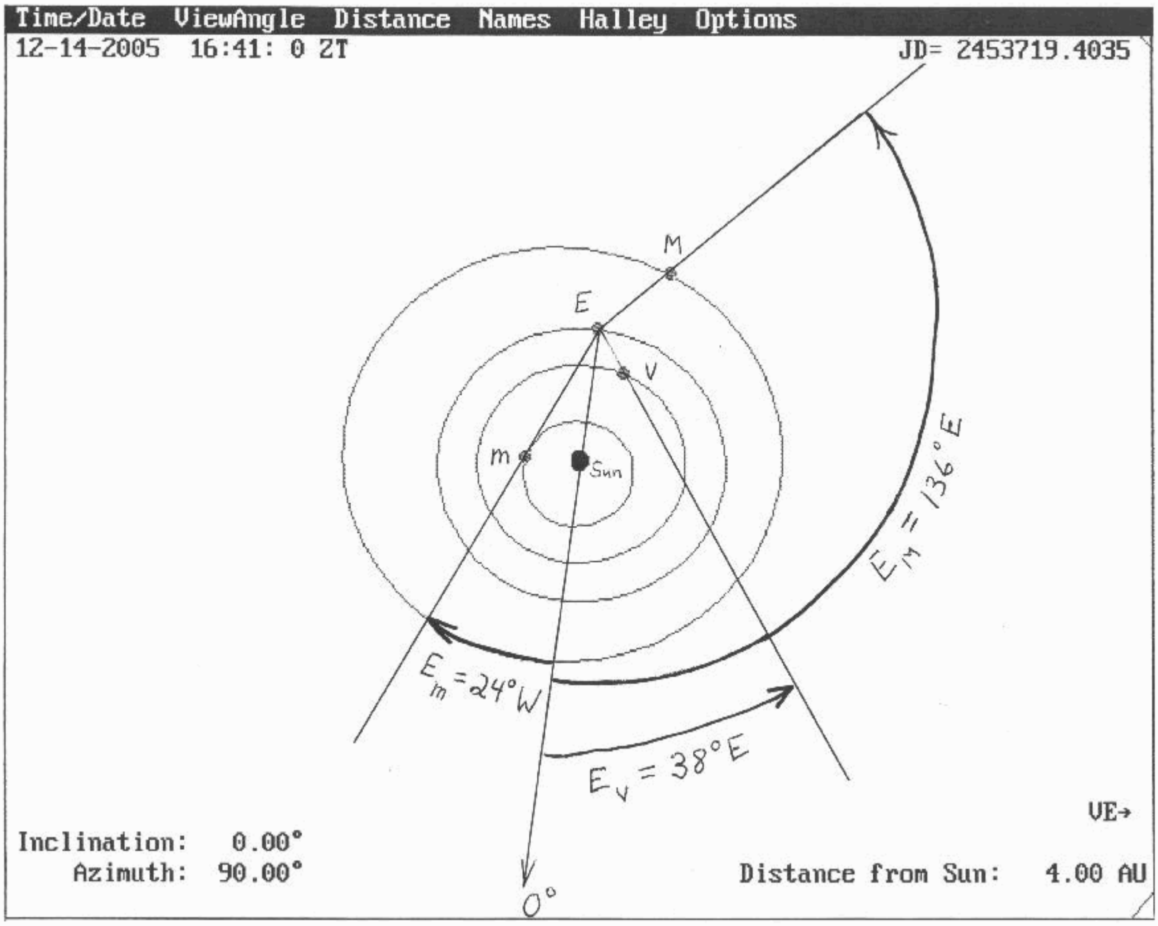
15. Use the value of the elongation you have determined for Venus on printout #2 and the equation

$$\mathbf{T_P = T_{\odot} - T_E ,}$$

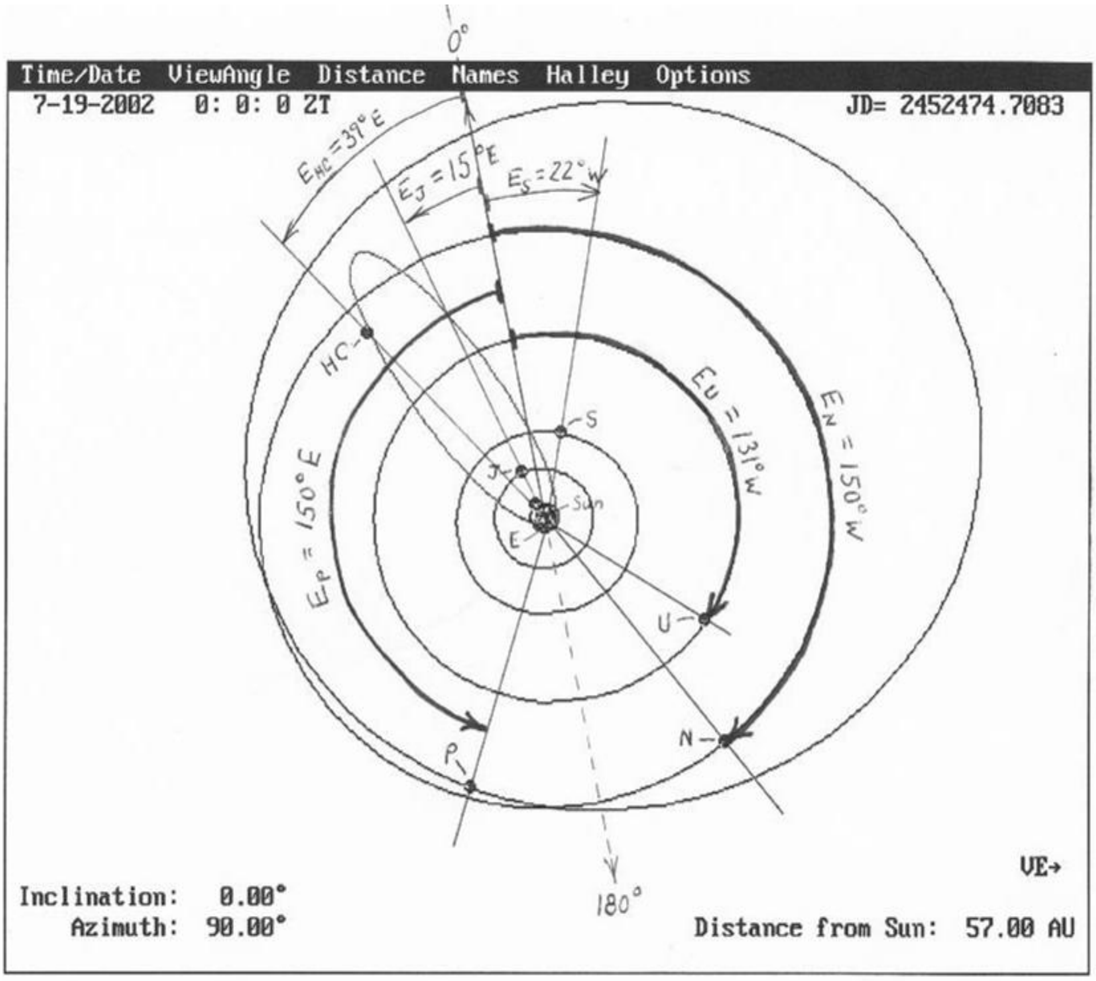
which was explained in the introduction, to compute the time Venus will rise. Do this calculation on the answer sheet as No. 10.

16. Similarly, compute the time Mars will set. Do this as No. 11 on the answer sheet

17. Now compute what time Saturn rises as No. 12.



Time/Date ViewAngle Distance Names Halley Options
12-14-2005 16:41: 0 ZT
JD= 2453719.4035
M
E
V
m
Sun
$E_M = 136°E$
$E_m = 24°W$
$E_V = 38°E$
VE→
Inclination: 0.00°
Azimuth: 90.00°
Distance from Sun: 4.00 AU
0°

0°
Time/Date ViewAngle Distance Names Halley Options
7-19-2002 0: 0: 0 ZT
JD= 2452474.7083
$E_{HC} = 39°E$
$E_J = 15°E$
$E_S = 22°W$
HC
S
J
Sun
E
$E_U = 131°W$
$E_N = 150°W$
$E_P = 150°E$
U
N
P
VE→
Inclination: 0.00°
Azimuth: 90.00°
180°
Distance from Sun: 57.00 AU

# EXERCISE 4.0 ANSWER PAGE

## Planetary Orbits and Configurations

1. Elongation of A from diagram in part I of Manual: ............... ____________________________
2. Elongation of B from diagram in part I of Manual: ............... ____________________________
3. Date of elongation: ____________________________
4. Elongation of Mercury: ....................................................... ____________________________.
5. Elongation of Venus: ____________________________
6. Configuration or Aspect name: ____________________________
7. Orbital class for Mercury and Venus: ................................ ____________________________
8. Mercury: ___________________ Venus:__________________ Mars: ____________________
9. Jupiter: ____________________ Saturn: ________________ Uranus: ___________________

   Neptune:___________________ Pluto: _________________ Halley's Comet _____________

10. Calculation of the time Venus rises:

    a. Elongation of Venus in degrees: _____________________

    b. Value of $T_E$ for Venus in hours and minutes with proper algebraic sign: ______________

    c. Value of $T_{\odot}$ for Sun: ____________________

    d. $T_P = T_{\odot} - T_E$ = _______________________

11. Calculation of the time Mars sets:

    a. Elongation of Mars in degrees: _____________________

    b. Value of $T_E$ for Mars in hours and minutes with proper algebraic sign: ________________

    c. Value of $T_{\odot}$ for Sun: ____________________

    d. $T_P = T_{\odot} - T_E$ = _______________________

12. Calculation of the time Saturn rises:

    a. Elongation of Saturn in degrees: _____________________

    b, Value of $T_E$ for Saturn in hours and minutes with proper algebraic sign: _______________

    c. Value of $T_{\odot}$ for Sun: ____________________

    d. $T_P = T_{\odot} - T_E$ = _______________________

End