Name: ____________

Date: ____________

Section: ____________

Astron 104 Laboratory #4
Orbital Motion of a Planet

Introduction

The nature of the Solar System was first derived from careful measurements of the positions of the planets in the night sky. We will reproduce some of those inferrences here.

When observing one of the **inner planets** (planets between the Earth and the Sun, namely Venus or Mercury), the planet always appears close to the Sun for a short time after sunset or before sunrise. By measuring how far from the Sun the planet is (the **elongation**) on different days of the year you can determine:

1. the length of Earth's year
2. the length of the other planet's year
3. the radius of the other planet's orbit, in Astronomical Units

All exercises below are accessed via the *Virtual Astronomy Lab.* To find them:

1. Click on *Virtual Astronomy* on the desktop
2. Click on *Start Virtual Astronomy Lab*
3. Click on *Unit 11: Orbital Motion of a Planet*

Assumptions

In order to simplify the calculations, we shall make some assumptions:

1. There are only two planets in this Solar System: Earth and Venus
2. Both planets move around the sun in perfectly circular orbits

3. Both planets orbit in the same direction
4. Both planets orbit in the same plane: the **ecliptic**
5. Neither of these is the real Earth or Venus. Instead they are **virtual** versions

Instructions

Once you have opened *Unit 11: Orbital Motion of a Planet*, click on *Planetary Motion*.

You are shown a view of the sky looking east (at sunrise) or west (at sunset). The position of the rising or setting Sun is shown, as is the position of those stars which are visible. Venus appears in the sky as a very bright star-like object. You can switch between sunrise and sunset by selecting the appropriate option under "Time of Day." This is important because Venus is sometimes visible in the evening (when it trails the Sun across the sky), and sometimes visible in the morning (when it precedes the Sun across the sky). You can progress through the year by selecting one of the buttons in the "Advance" section. Depending on which button is selected, you can advance slowly (one day at a time), or rapidly (up to 10 days at a time).

As part of this unit, you will need to measure the **elongation** of Venus. To measure the elongation *click on the center of the rising/setting Sun and then hold down the left mouse button while you drag the cursor to the center of Venus*. The elongation which is displayed is that of the present cursor position.

Exercise 1-Determination of the Length of Year for Earth [15 points]

There are two indicators that you can use to determine the length of the year:

1. Position of the Sun:
   (a) Because of the tilt of Earth's rotation axis, on the summer solstice the Sun rises north of due east, and sets north of due west.
   (b) On the winter solstice the Sun rises south of due east and sets south of due west.
   (c) On other days during the year the position of the rising and setting Sun lies between these two extremes.
   (d) As you progress from day to day through the year you can see that the position of the Sun changes.
   (e) Identify a particular point in where the Sun rises. For example, the summer solstice.
   (f) By measuring how long it takes to get from (say) the summer solstice to the next summer solstice tells you the length of the year.
2. Positions of the other stars:

(a) The constellations which appear in the sky are dependent on the position of the Earth in its orbit around the Sun

(b) If you note the pattern of the stars on one night, then when that same pattern returns again to the same position in the sky, one year will have passed.

Note: Whichever method you choose, you can improve the accuracy of your results by measuring the number of days corresponding to multiple years (for example ten years) and then calculate the length of one year from this number.

1. Determine the length of the year based on the position of the Sun [**5 pts**].

2. Determine the length of the year based on the positions of the other stars [**5 pts**].

3. Compare the results using the percentage equation [**5 pts**]:

$$\frac{Y_1 - Y_2}{Y_1} \times 100 = \text{percent difference}$$

Exercise 2-Determination of the Maximum Elongation of Venus [20 points]

The **elongation** of Venus is illustrated in Figure 1:

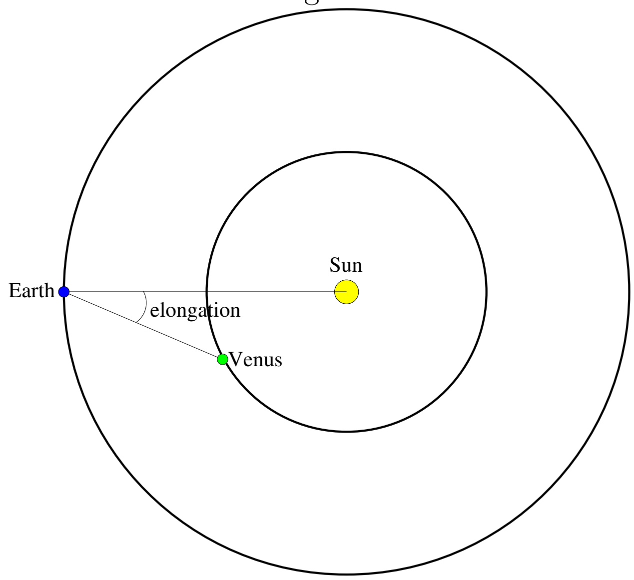


Figure 1: A cartoon showing how elongation is defined

It is the angle between the Sun and Venus as seen from the Earth.

Using measurements of the elongation of Venus for different days allows you to calculate the radius of its orbit:

1. As Venus orbits around the Sun its elongation changes
2. At the maximum elongation, the line of sight from you to Venus is **tangent** to Venus's orbit:

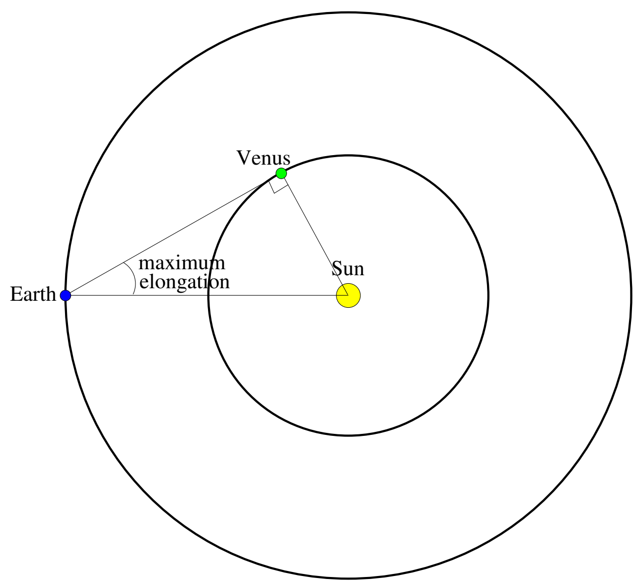


Figure 2: A cartoon showing maximum elongation

3. You will need to measure the elongation of Venus at various points in its orbits around the Sun.
4. You will need to make measurements over an extended period, perhaps as many as 1,500 days.
5. However, you do not need to make measurements every single day: try every 20 days, although if time is short every 50 days gives acceptable results.
6. Assign a **positive** sign to the elongation if it is measured at **sunrise**, and a **negative** sign if measured at **sunset**.
7. Graph your results on the paper provided [**15 pts.**]

Your results should be similar to Figure 3:

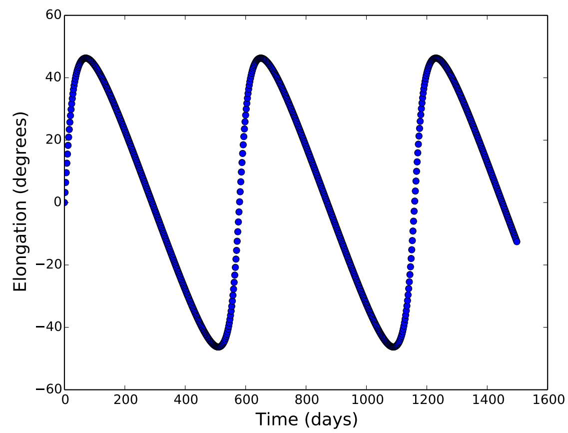


Figure 3: A plot of the elongation of Venus

Once you have your plot, determine maximum elongation of Venus. For example, in Figure 3 the maximum elongation would be about 46 degrees on either side of the Sun. What do you find for the maximum elongation of Venus [**5 pts**]?

Exercise 3-Determination of the Orbital Radius of Virtual Venus [20 points]

Now that you have the maximum elongation, you can determine the radius of the orbit of Venus as measured in Astronomical Units. As mentioned earlier, when Venus is at maximum elongation, our view of Venus is **tangent** to its orbit (Figure 2).

1. Start with a clean piece of paper.
2. Draw a line close to the edge to represent the line from Earth to the Sun. Make the line as long as possible to minimize measurement errors. Mark one end of the line to represent Earth (your position) and the other end that of the Sun. This line represents the radius of Earth's orbit.
3. Starting at the end of this line which you assigned as Earth, and using a protractor, draw a second line angled relative to the first at the maximum elongation.
4. Draw a third line starting at the Sun and ending on the second line at the point which is closest to the Sun. This third line represents the orbital radius of Venus.
5. Measure the length of the first and third lines. The ratio of these:

$$\frac{\text{length of third}}{\text{length of first}}$$

is the radius Venus's orbit, in Astronomical Units. What do you get?[**5 pts**]

Exercise 4-Determination of Length of Year for Venus [20 points]

In the graph at the end of this unit, Earth's orbit is represented by the outermost circle with the Sun at the center. We will take this circle to have a radius equivalent to 1 AU.

1. Draw a second circle on this diagram, concentric with the outermost circle, and which has a scaled radius equal to the orbital radius of Venus, in Astronomical Units. i.e.,

   $$\text{radius of inner circle} = \text{radius of outer circle} \times \text{radius of Venus's orbit in AU}$$

   This circle represents the orbit of Venus.

2. Plot the position of Earth every 20 days around the outermost circle (or whatever time interval you used to gather your elongation data). You can calculate how far Earth moves from the length of its year. For example, if Earth's year is 480 days long, then each day it will move:

   $$\frac{360\,\text{degrees}}{480\,\text{days}} = \frac{3}{4}\frac{\text{degree}}{\text{day}}$$

   and so each 20 day interval corresponds to a movement of

   $$\frac{3}{4}\frac{\text{degree}}{\text{day}} \times 20\,\text{days} = 15\,\text{degrees}$$

   around the outermost circle.

3. On each of these days, use the corresponding angle of elongation and a protractor to draw a line from Earth to the orbital circle of Venus. The intersection of the line and orbital circle gives the position of Venus on this particular day (as in Figure 1).

   Be careful. The line and the orbital circle will have **2** possible intersections. One is closer to the Earth and one is further away. If Venus is changing elongation **quickly**, is it more likely close to the Earth or further away? And if it is changing elongation **slowly**? Can you use this to figure out which is the right intersection?

4. Continue plotting the position of Venus until you have completed a full circle. Determine the time it takes for Venus to orbit the Sun once. The length of Venus's year is [**5 pts.**]:

Exercise 5-Kepler's Laws [25 points]

You should now be able to fill in the following data table:

1. Orbital radius for virtual Earth: $r_1 = 1$ AU
2. Orbital radius for virtual Venus: r_2= ______AU
3. Length of the year for virtual Earth: T_1 = ______days
4. Length of the year for virtual Venus: T_2= ______days

Select *Check your answers* from the overhead menu and input your results. Correct results will be indicated with a check mark. This data should fit Kepler's 3rd Law which states that:

$$\frac{r^3}{T^2}$$

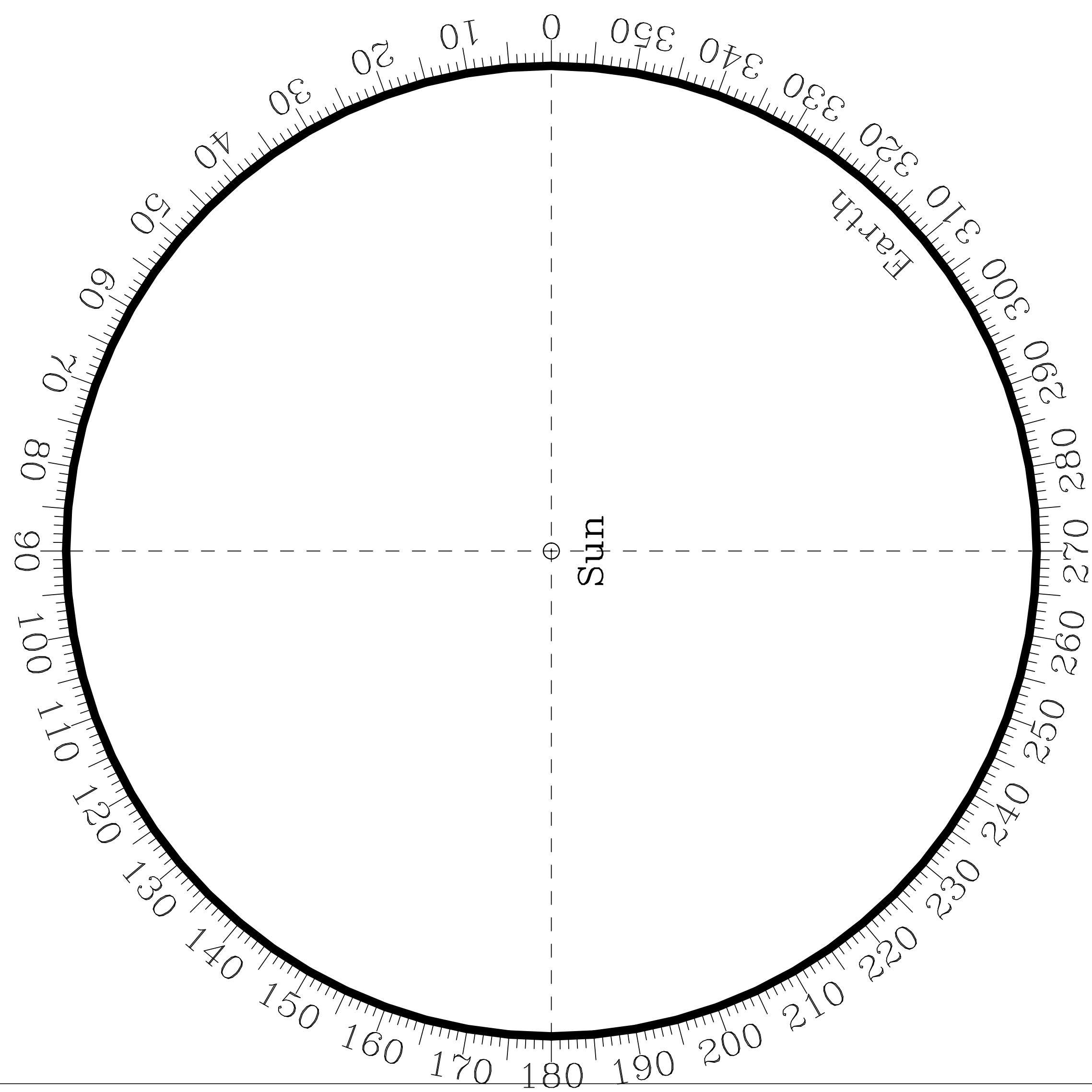
should be the same for both planets. Calculate the ratios for the two planets and enter the results here (10 points):

1. Virtual Earth: r_1^3/T_1^2= ________
2. Virtual Venus: r_2^3/T_2^2= ________
3. Are these numbers the same?

Grid for elongation vs. time:

Name: **Date:**

Diagrams:


Sun
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