

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Section: \_\_\_\_\_

## Astron 104 Laboratory #2a

### A Step Toward A More Complicated Universe: The Motion of Mars

This table contains Heliocentric Ecliptic longitudes of Earth and Mars at 20 day intervals, centered on opposition.

	Date	Earth Longitude	Mars Longitude
1	27 Dec., 1996	95.5°	141.5°
2	16 Jan., 1997	116.0°	150.5°
3	05 Feb., 1997	136.0°	159.0°
4	25 Feb., 1997	156.5°	168.0°
5	17 Mar., 1997	176.5°	176.5°
6	06 Apr., 1997	196.0°	185.5°
7	26 Apr., 1997	216.0°	194.5°
8	16 May, 1997	235.0°	204.0°
9	05 Jun., 1997	254.5°	213.0°

1. On the supplied planetary orbit chart, locate the orbits of Earth and Mars.
2. Locate the longitude for Earth's first position given on the longitude scale.
3. Place a ruler on the chart to line up with that position on the scale and the Sun's position at the center.
4. Mark the position on the Earth's orbit where that line intersects it, and label it "1."
5. Repeat steps 2–4 for the first position of Mars in its orbit, and also label it "1."
6. Draw a line between the two points labeled "1," and then extend that line out beyond the orbit of Mars to the horizontal line at the bottom of the page.
7. Put a dot at the end of the line you've just drawn, and also label it as "1."
8. Repeat the above steps for all the remaining data points, labeling them "2" through "9" and extending them all the same length beyond the orbit of Mars to the horizontal line at the bottom of the page. **20 pts. total**

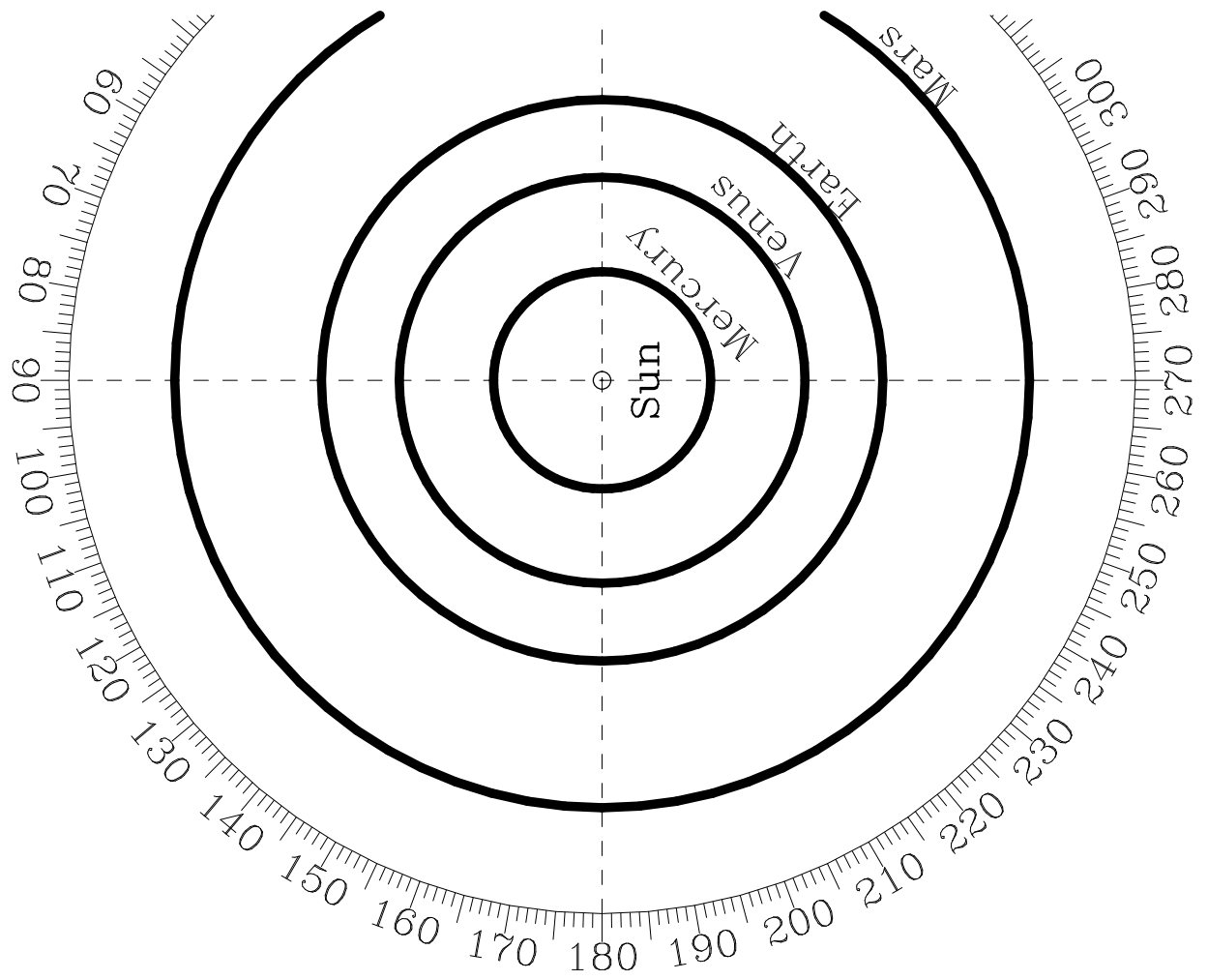
9. Draw a dashed (or colored) line from numbered dot to dot in order. The resulting figure will approximate the path of Mars against the background stars during the 160 period covered by the data. What do you notice? **10 pts.**

10. Why is this pattern observed? **10 pts.**

11. Look at:

<http://astro.unl.edu/classaction/animations/renaissance/retrograde.html>

This should illustrate the same phenomenon as you just worked out. If not, check your work.



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## Astron 104 Laboratory #2b

### The Orbit of Mars

#### Section 1.3

**Note: Use a pencil with a sharp point! Mark your data as accurately as possible.**

This table contains measurements by Tycho Brahe. There are 5 sets of data, each of which contains the measurements for two dates. The two dates in each set are separated by a Martian year (687 days), so Mars was at the same point in its orbit.

Date	Heliocentric longitude of Earth	Geocentric longitude of Mars
Feb 17, 1585	159°	135°
Jan 5, 1587	115°	182°
Sep 19, 1591	5°	284°
Aug 6, 1593	323°	347°
Dec 7, 1593	86°	3°
Oct 25, 1595	41°	49°
Mar 28, 1587	196°	168°
Feb 12, 1589	153°	218°
Mar 10, 1585	179°	131°
Jan 26, 1587	136°	184°

Because the length of an Earth year is less than a Martian year, Earth will be at a different point in its orbit on each of the two dates.

On the chart, the circle represents the orbit of the Earth around the Sun (at the center of the circle). The line from the center to the right edge represents the basic 0° direction in space from which all of Brahe's angles are measured (this is the direction of the Sun as seen from Earth on the Vernal equinox).

If we draw a line from the Earth showing the direction that Mars appeared in the sky on each date in a set, we can determine the location of Mars as the point where the two lines meet.

Once we have used the 5 sets of dates to plot 5 points on Mars' orbit, we will investigate the shape of the orbit.

In the table, the position of the Earth is the **heliocentric longitude**, i.e., the angle of the Earth from the reference line as seen from the Sun. The position of Mars is given as **geocentric longitude**, i.e., the angle of Mars from the reference line as seen from the Earth.

## Procedure

1. With a protractor centered on the Sun (center of the circle) and with the Vernal equinox as the starting line, mark the position of the Earth for the first date in the table in a counterclockwise direction. Label the point  $E_{1,1}$ .
2. The angle from the Earth to Mars is the geocentric longitude of Mars. Center the protractor on the point  $E_{1,1}$ , and, along a parallel to the Vernal equinox, measure the geocentric longitude counterclockwise. Mark the direction of Mars as  $O_{1,1}$ .
3. Connect the two points  $E_{1,1}$  and  $O_{1,1}$  with a straight line.
4. Follow this procedure for the second date, labeling the points  $E_{1,2}$  and  $O_{1,2}$ . Connect  $E_{1,2}$  and  $O_{1,2}$  with a straight line.
5. The point of intersection of these two lines ( $E_{1,1}O_{1,1}$  and  $E_{1,2}O_{1,2}$ ) is a point on Mars' orbit. Label this point  $M_1$ .
6. Repeat the above for the remaining four pairs of dates in the table, using similar notation. Label these points on Mars' orbit  $M_2$  through  $M_5$ .
7. Using a ruler, draw a line between the points  $M_1$  and  $M_2$ . Mark the midpoint (center) of this line and label it C. Draw a circle centered on it so that both points  $M_1$  and  $M_2$  fall on the circle. This will represent the orbit of Mars, if it had a circular orbit.
8. Note where the points  $M_2$  through  $M_5$  fall. Based on how closely the points are to the circle, do you think that Mars' orbit could be a circle? How about the location of C relative to the Sun? Please explain your answer in detail. **20 pts. total**

9. To see how good an approximation an ellipse is to the actual orbit of Mars, we will do the following: an ellipse has two foci. In the case of a planet, the Sun is at one focus. The “empty focus” lies along the major axis in the direction of point C (from the Sun) with **C being in the middle of the two foci**. To find the “empty focus” point, mark the point F along the line drawn from the Sun to point M<sub>1</sub>, so that FC=SC.
10. Draw an ellipse with the Sun and point F as foci. Fix pins at both foci. Attach a length of string to the pins so that a pencil point just reaches the perihelion (M<sub>2</sub>) or aphelion (M<sub>1</sub>) points when the loop is fully extended. Feel free to ask one of your fellow students for their assistance in keeping the pins fixed. Is the ellipse or a circle a better description of Mars’ orbit? Please explain your answer quantitatively. **10 pts.**
11. Find the distance from the Sun to Mars in Astronomical Units (one Astronomical Unit is the distance from the Earth to the Sun). Do this by measuring the distance M<sub>1</sub>M<sub>2</sub> and comparing this to the diameter of Earth’s orbit, i.e.:

$$\text{Mars – Sun distance} = \frac{\text{diameter of Mars' orbit}}{\text{diameter of Earth's orbit}} \text{ AU}$$

**10 pts.**

12. The eccentricity  $e$  of the orbit is the ratio of the distance between the Sun and point C to the distance from point C to  $M_1$  (semi-major axis of the orbit):

$$e = \frac{SC}{M_1C}$$

What is  $e$ ? **10 pts.**

13. What do you conclude from this exercise regarding the shape of the orbits of planets? Why did it take so long to conclude that planets travel on ellipses? **10 pts.**

