Name: ____________________

Date: ____________________

Section: ____________________

Astron 104 Laboratory #5
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 lin 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.

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_1, 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_2) or aphelion (M_1) 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.

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 M1M2 and comparing this to the diameter of Earth's orbit, i.e.:

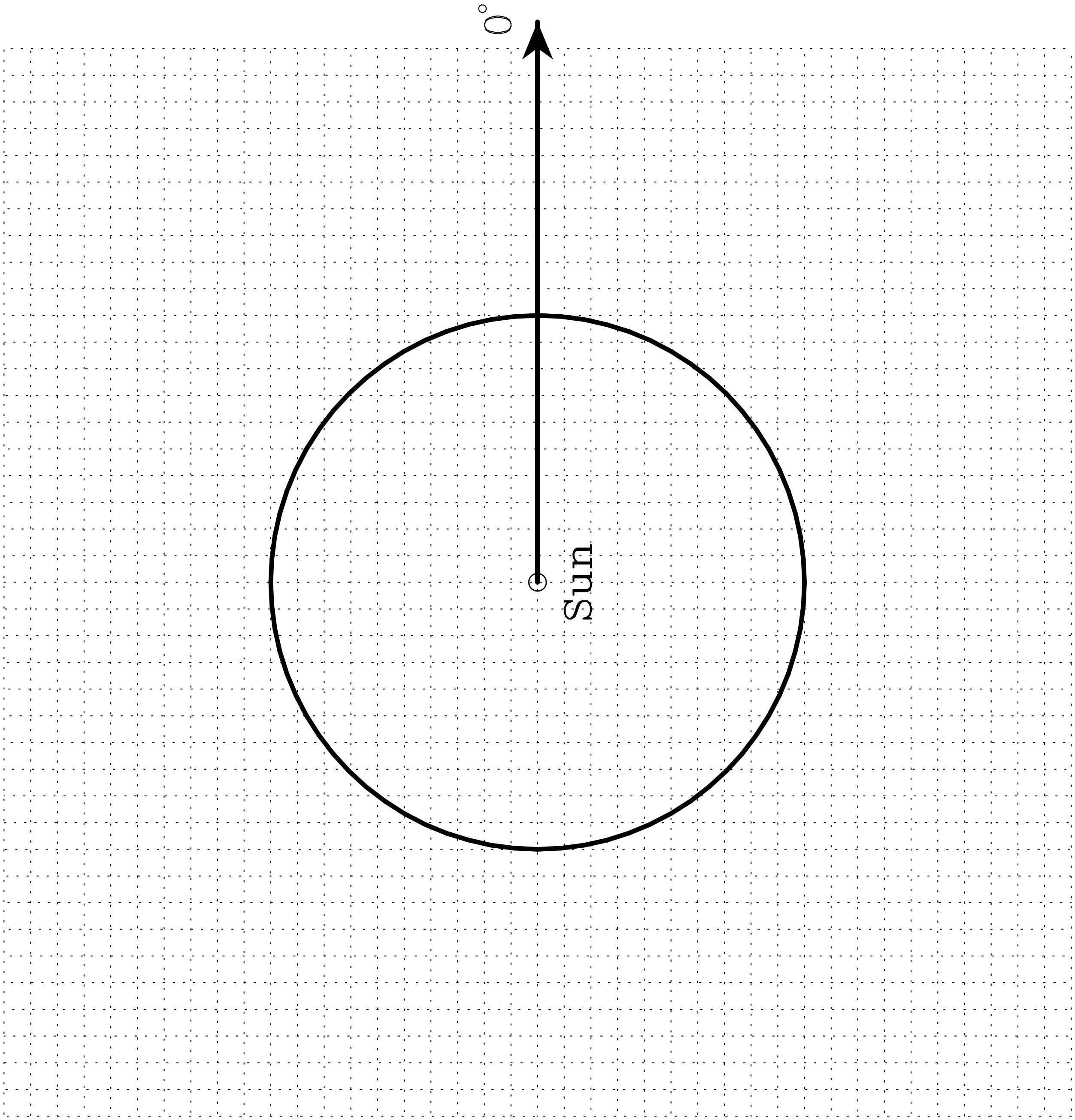
$$\mathrm{Mars - Sun\ distance} = \frac{\mathrm{diameter\ of\ Mars'\ orbit}}{\mathrm{diameter\ of\ Earth's\ orbit}}\,\mathrm{AU}$$

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):

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

What is e?

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?


0°
Sun