Copernicus and the Proportions of the Solar System

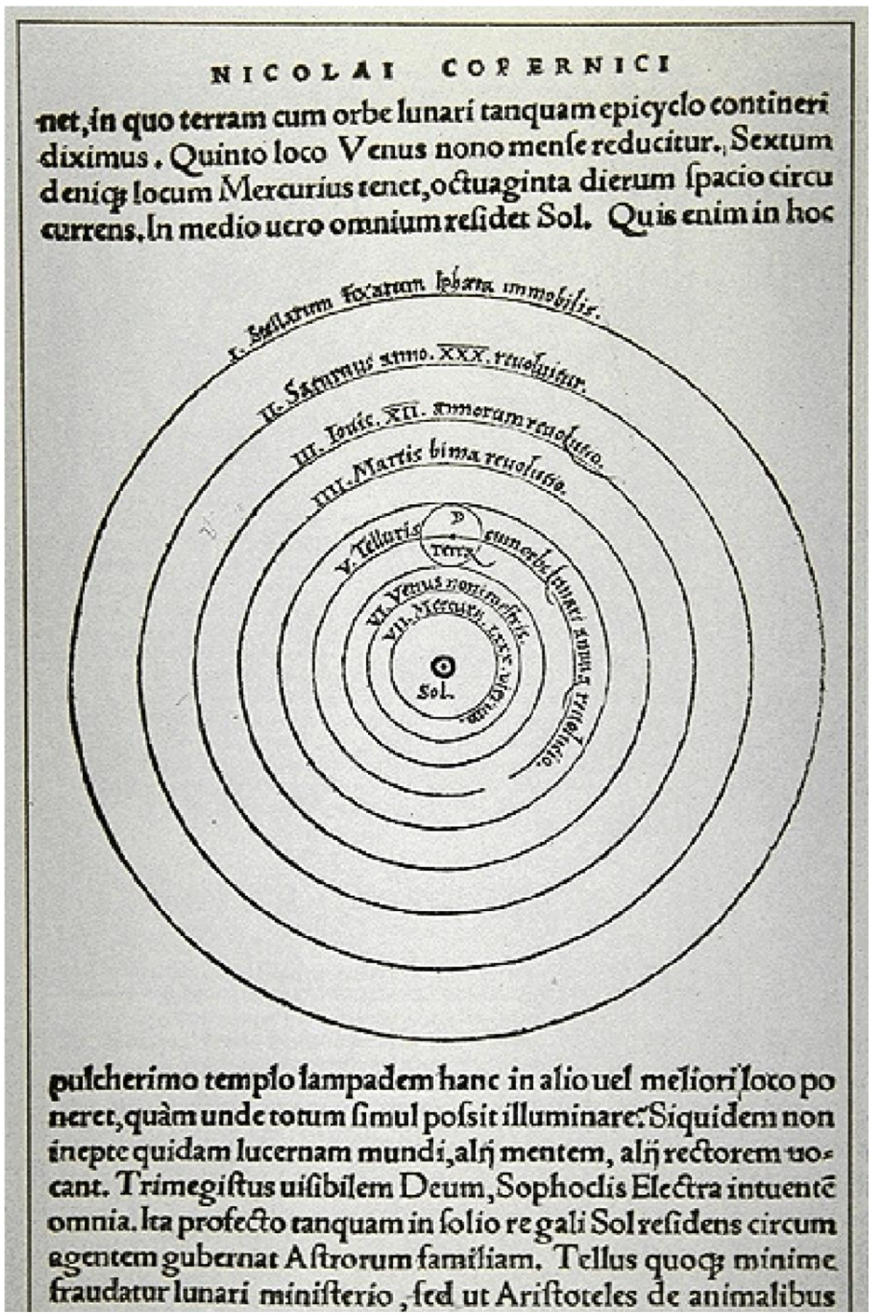
Objective:

In this experiment, we will measure the size of the orbit of Venus, relative to that of the Earth, using a method due to Copernicus.

Materials required:
compass ruler
protractor calculator

Introduction:

In the early 1500's, Copernicus worked out the relative sizes of planetary orbits to an accuracy of 1%. His results were published in De Revolutionibus Orbium Coelestium (On the Revolution of the Celestial Orbs) in 1543, the year of his death. An important page from that book is shown on the right. Note that he has the order of the planets right, and that the Moon is shown in orbit around the Earth. The outermost circle represents the fixed stars. This picture was not drawn to scale.


NICOLAI COPERNICI

net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono menſe reducitur. Sextum deniq; locum Mercurius tenet, octuaginta dierum ſpacio circu currens. In medio uero omnium reſidet Sol. Quis enim in hoc

pulcherimo templo lampadem hanc in alio uel meliori loco poneret, quàm unde totum ſimul poſsit illuminare? Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegiſtus uiſibilem Deum, Sophoclis Electra intuentē omnia. Ita profecto tanquam in ſolio regali Sol reſidens circum agentem gubernat Aſtrorum familiam. Tellus quoq; minime fraudatur lunari miniſterio, ſed ut Ariſtoteles de animalibus

Copernicus made some assumptions concerning the geometry of the solar system. His

assumptions were not exactly right, but weren't off by too much either. (Don't criticize Copernicus for not having instruments that were developed fifty years after his death.) Assumptions: (We will use the first two of these assumptions in this experiment.)

1) The planets move in circles with the Sun in the center.
2) The orbits of the planets lie in the same plane.
3) The planets travel at uniform speed.

As seen from the Earth, Venus is never found opposite the Sun. The angle between Venus and the Sun measured along the ecliptic (apparent orbit of the Sun) is called the elongation. Here is a table of maximum elongations for the year 2001:

Jan. 16 Venus reaches maxi mum elongation 47 degrees (sets later than the Sun)

June 8 Venus reaches maximum elongation 48 degrees (rises earlier than the Sun)

The disparity (47 vs. 48 degrees) reflects the failure of assumption 1). If the orbits of the Earth and Venus were exactly circular, the angle of maximum elongation would always be the same, and the value would always be about 46.3 degrees. Shown below is a sky

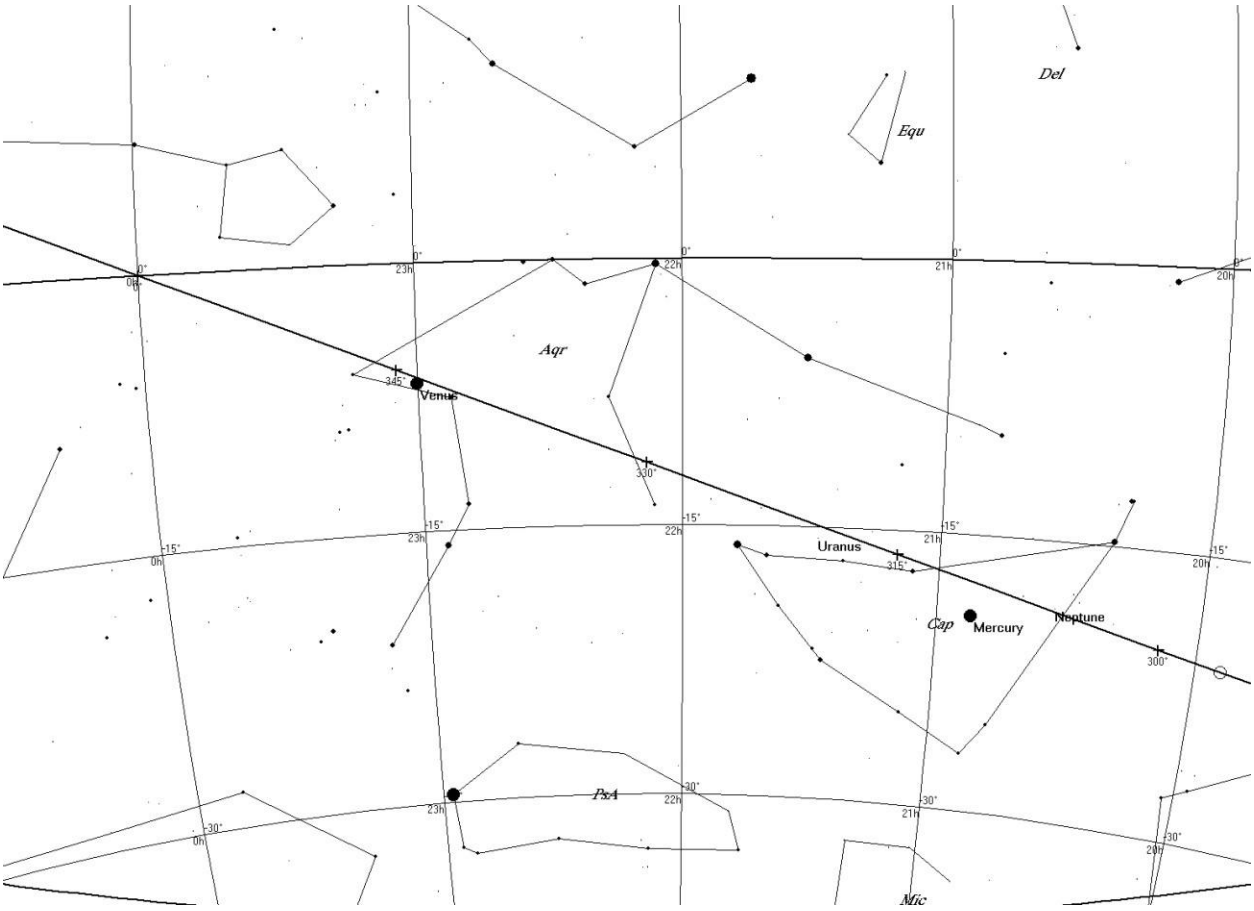
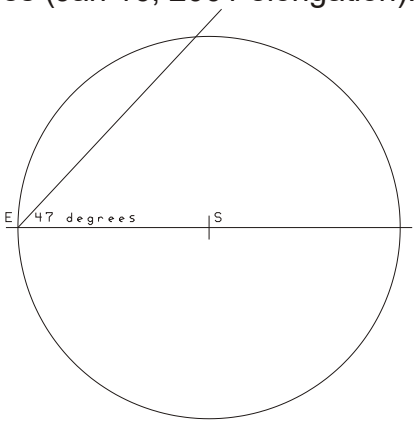


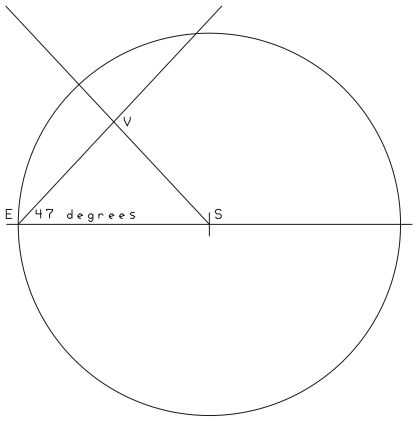
chart for Jan. 16, 2001, plotted in such a way that the ecliptic is a straight line. The Sun is shown as an open circle on the ecliptic, on the lower right.

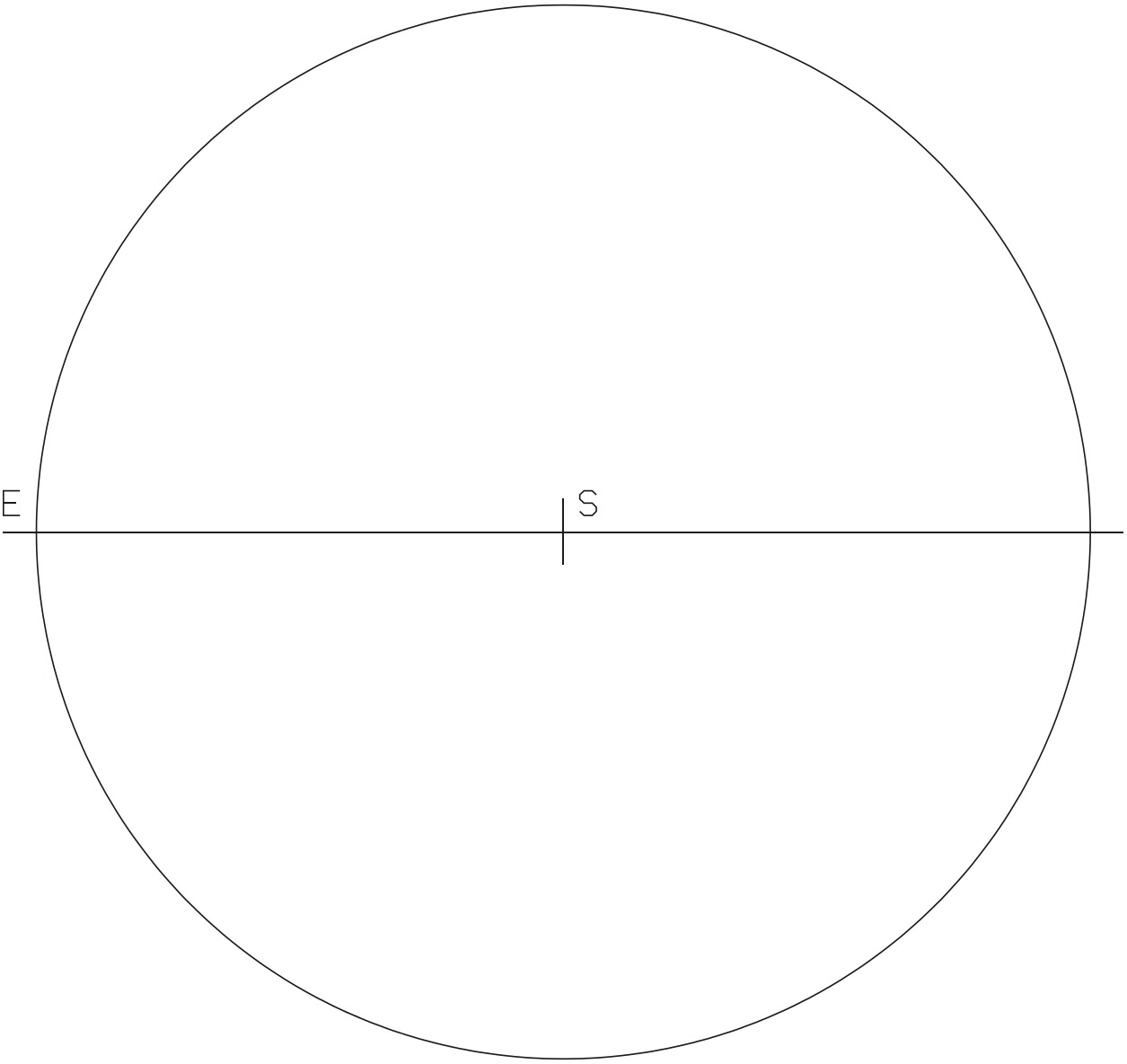
Procedure: Find the relative size of the orbit of Venus geometrically. Draw on the figure on the next page. The Sun is at the center; the Earth is placed on the left.

Step 1. Place the center mark of the protractor on the point representing the earth, and mark off an angle of 47 degrees (Jan 16, 2001 elongation).



Step 2. Place the center mark of the protractor on the point representing the Sun, and mark off an angle towards the left of 43 degrees (90 - 47 = 43). Draw a long line from the point representing the Sun through the 43-degree mark. The intersection of the two lines you have drawn is the location of Venus. The lines cross at a 90-degree angle.





Step 3. Using the centimeter side of the ruler, measure the distance from the Sun to the Earth. Measure the distance from the Sun to Venus. Using the calculator, find the distance from the Sun to Venus in AU (AU=astronomical unit = average Sun-Earth distance)

$Sun - Venus\ distance\ in\ AU = \frac{Sun-Venus\ distance\ in\ cm}{Sun-Earth\ distance\ in\ cm}$ = _____/_____ = _____

Using the calculator, find the sine of 47 degrees $\frac{Sun-Venus\ distance}{Sun-Earth\ distance}$ _____

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Name_____Date_____