

Introduction: Modern weather satellites may be launched into a geosynchronous orbit in which they travel 15° every hour. They seem to be stationary to an observer on Earth.

This lab considers a hypothetical situation in which two weather satellites are launched. The launch into orbit was successful. However, when the booster rockets were fired to place them into their geosynchronous orbits, there was a small directional error on one of the two satellites. As a result, that satellite went into an elliptical orbit rather than the circular orbit planned. The resulting situation is shown in Figure 1 in which both satellites have the same period of revolution. The maverick satellite is approximately twice as fast as the stationary satellite at perigee, but at apogee it is moving approximately at half the speed of the one in circular orbit.

Objective: You will examine some of the properties of satellites in circular and elliptical orbits to determine some of the laws that govern the motion of a satellite around its primary body.

Vocabulary:

Geosynchronous

Primary body

Perigee

Apogee

Velocity

Maverick

Procedure:

1. Determine the eccentricity of the circular orbit by making the following measurement and calculations. Enter the results in the data table.
 - a. Measure the major axis (diameter) of the circular path in centimeters.
 - b. Note that the focal distance of a circular orbit is zero.
 - c. Calculate the eccentricity using the equation:

$$e = \frac{d}{L} \quad \text{where } e = \text{eccentricity, } d = \text{focal distance, } L = \text{length of major axis}$$

2. Determine the eccentricity of the elliptical orbit by using the method shown in Procedure 1. Enter the results in the data table.
 - a. Measure the major axis of the elliptical orbit in centimeters.
 - b. Measure the focal distance between F_1 (the center of the Earth) and F_2 .
 - c. Calculate the eccentricity using the equation given in Procedure 1.
3. Determine the area of the pie-shape (radius vector area) covered by the circular orbit in a period of 1 hour by making the following measurements and calculation. Enter the results in the data table.
 - a. Measure angle R (to the nearest degree)
 - b. Measure the radius from the center of Earth to perimeter of the circular orbit at R. Measure to the nearest tenth of a centimeter.
 - c. Calculate the area using the equation:

$$A = (\text{angle } R) \times (\text{radius } R)^2$$

4. Determine the area covered by the elliptical orbit in one hour at perigee, following these measurements and calculations:
 - a. Measure angle P to the nearest degree.
 - b. Measure the radius from the center of Earth to the perimeter of the elliptical orbit at P. Measure to the nearest tenth of a centimeter.
 - c. Calculate the area using the equation:

$$A = (\text{angle P}) \times (\text{radius P})^2$$

5. Determine the area covered by the elliptical orbit in one hour at apogee, following these measurements and calculations:
 - a. Measure angle A to the nearest degree.
 - b. Measure the radius from the center of Earth to the perimeter of the elliptical orbit at A to the nearest tenth of a centimeter.
 - c. Calculate the area using the equation:

$$A = (\text{angle A}) \times (\text{radius A})^2$$

6. With a tape measure, measure the length of the arcs travelled by the elliptical satellite in one hour at:
 - a. Perigee (from position 1 to position 2)
 - b. Apogee (from position 3 to position 4)
 Enter these measurements in the data table.
7. Construct another 15° angle from the center of Earth to the circular orbit at a different position from R. Label this angle S.
8. With a tape measure, determine the length of the arcs traveled by the geosynchronous (circular) satellite in one hour for:
 - a. Angle R
 - b. Angle S (which you just constructed).
 Enter these measurements in the data table.

Data Table

	Circular orbit	Elliptical orbit
Major axis		
Focal distance		
Eccentricity		

	Angle	Radius	Area (cm²)
Vector R			
Vector P			
Vector A			

	Length of arc
Ellipse at perigee	
Ellipse at apogee	
Circle, Angle R	
Circle, Angle S	

Figure 1

Discussion questions

1. What is the primary body around which these satellites orbit? _____
2. Where is the primary body located with respect to the elliptical orbit of the maverick satellite? _____

3. How did the length of the radius change between apogee and perigee for the elliptical orbit? _____

4. What general statement can be made about the areas covered by each satellite over a period of one hour? _____

5. Compare the distance traveled in one hour by the maverick (elliptical orbit) satellite near perigee (positions 1-2) with the distance it traveled near apogee (positions 3-4). _____

6. What can you infer about the velocity of a satellite in an elliptical orbit as it travels from perigee to apogee? _____

7. Where in its elliptical orbit would a satellite have the greatest kinetic energy (energy of motion)? _____

8. Do any planets have the same eccentricity as the satellite with the circular orbit? _____
9. Examine the eccentricities of the planets in the *ESRT*.
What is the shape of the orbits of all of our planets? _____
10. Which planet has the greatest change in radius as it revolves around the Sun? _____
11. When the maverick satellite's orbit is corrected and becomes more circular, what would be the effect on each of the following?
 - a. Radius _____
 - b. Velocity _____
 - c. Area swept every hour _____

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12. What is the relationship between the period of revolution and mean distance from the Sun? _____

13. Which planet has the longest period of revolution? _____

14. What planet's day is closest in length to its year? _____

15. State Kepler's three laws of planetary motion.

First Law - _____

Second Law - _____

Third Law - _____
