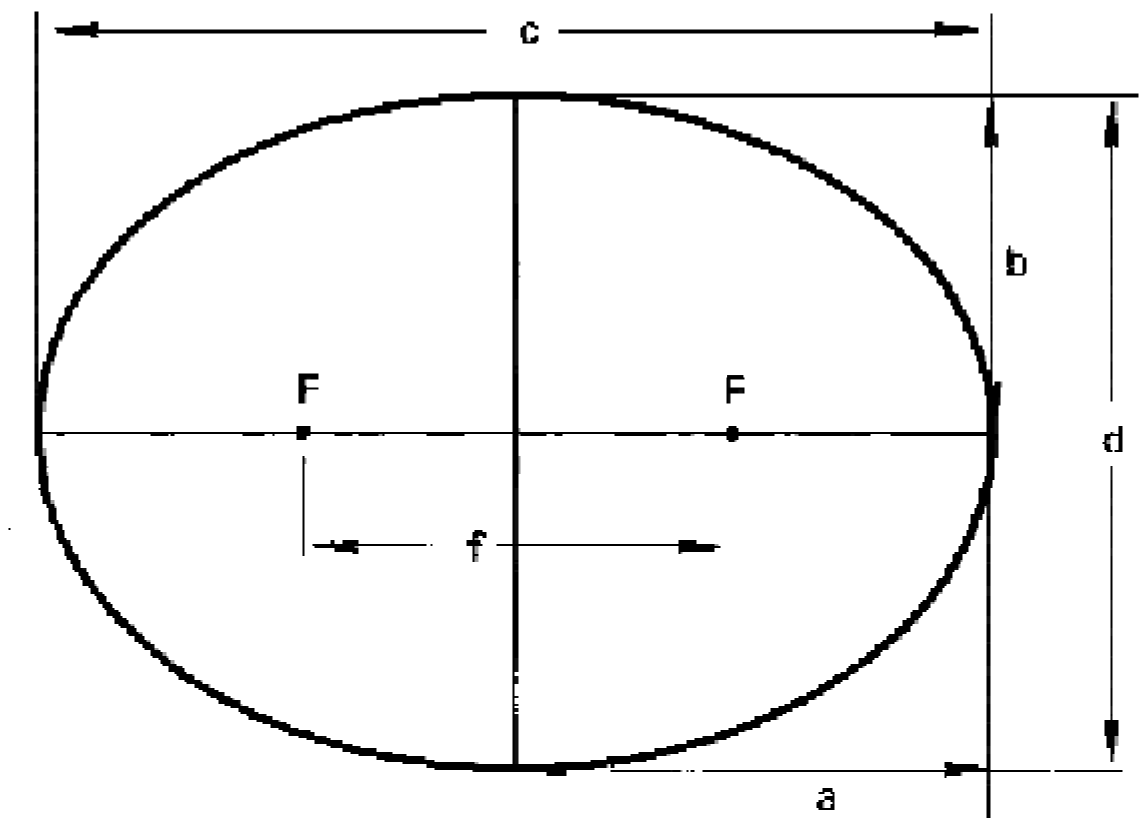
Kepler's Laws

I. Introduction

The purpose of this lab is to study Kepler's laws as applied to the lunar orbit of the Explorer 35 satellite. Kepler's laws are valid not only for planets orbiting the sun but for any two objects orbiting each other under the influence of their mutual gravitational attraction. By using a scale drawing of Explorer 35's orbit you will verify the application of Kepler's laws to artificial satellites. Kepler's laws as stated for planetary orbits are given below:

Law 1: The orbit of a planet about the Sun is an ellipse with the Sun at one focus.

GEOMETRY OF AN ELLIPSE

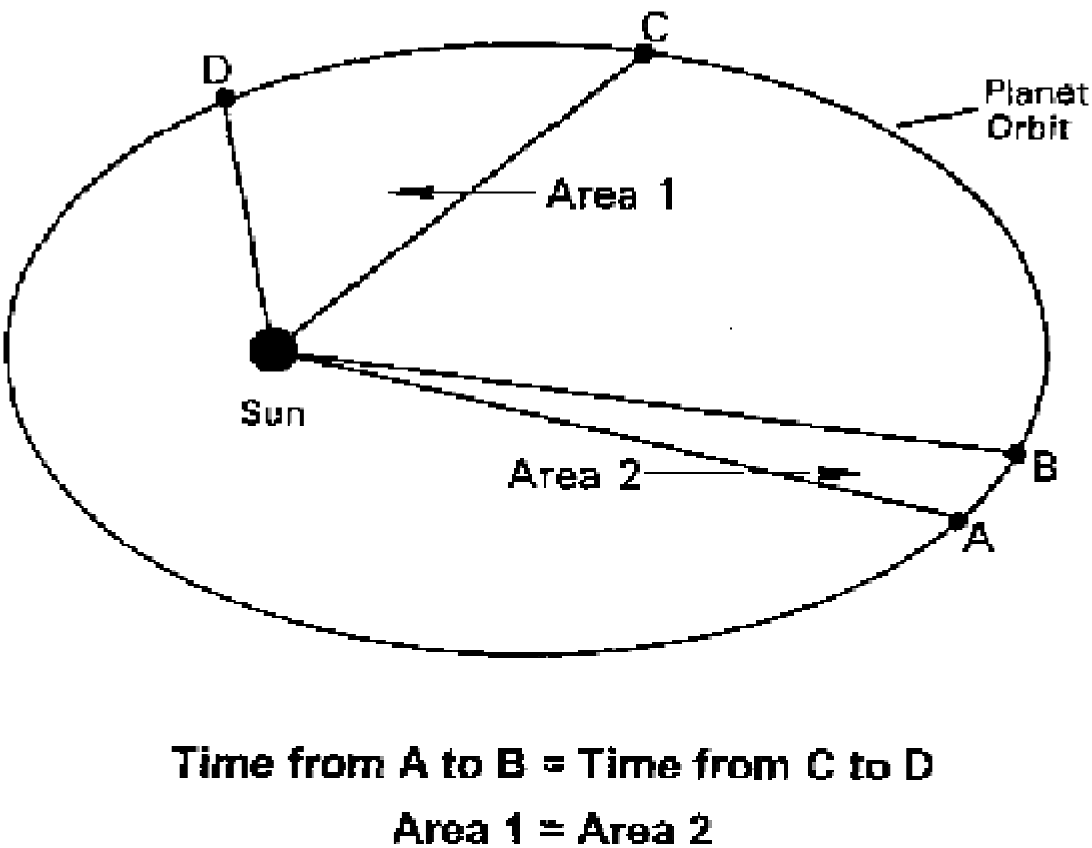


F - focus points	b - semi-minor axis
f = foci separation	c = major axis
a = semi-major axis	d = minor axis

Eccentricity of an ellipse is a measure of its "flatness." Eccentricity (e) is defined as the distance between the foci divided by the major axis.

$$e = \frac{f}{c}$$

Law 2: A line joining a planet and the Sun sweeps out equal areas in equal intervals of time.



Law 3: The squares of the sidereal periods of the planets are proportional to the cubes of their semi-major axes.

$$P^2 = ka^3$$

where "P" is the sidereal period of the planet in years and "a" is the semi-major axis of the planet in astronomical units (AU.). For any two bodies orbiting each other Newton generalized this law to read:

$$P^2 = \frac{4\pi^2}{G} \frac{a^3}{(m + M)}$$

where m and M are the two masses, P is the period of the orbit, G is the universal gravitational constant, and a is the semi-major axis.

II. Procedure

In July 1967 NASA launched the Explorer 35 spacecraft to study the solar wind and solar x-ray emission. An accurate plot of the orbit is on the last page.

1. Using a ruler and protractor draw in the major and minor axis and label them on your graph.

   HINT: The major axis must divide the satellite's orbit into two equal parts. It must go across the widest part of the orbit. The major axis has five key points that must be on it. Any two of these can be used to draw in the major axis.

   · The two foci (the Moon occupies one focus).
   · The center of the orbit.
   · The point in the orbit closest to the Moon (periluna).
   · The point in the orbit farthest from the Moon (apoluna).

   The minor axis is perpendicular to the major axis and must pass through the center of the orbit (bisect major axis).

2. Locate and label the foci of the orbit.

3. Label the moon's center point and the periluna and apoluna points.

III. Calculations and Questions

1. Verify Kepler's first law by the method outlined by your lab instructor. Show your work on the graph and explain the results below.

2. Calculate the eccentricity of the orbit.

3. Verify Kepler's 2nd law by the method of equal areas. Show your work on the graph and explain the results below.

4. At what point in its orbit is Explorer 35 moving with the greatest speed? (periluna or apoluna)

5. Using Kepler's 3rd Law ($P^2 = ka^3$) calculate the orbital period of Explorer 35. Complete the following steps:

a. ________________ cm — Measure the Moon's diameter from the orbit.

b. 3.46×10^6 m — Diameter of the moon in meters.

c. ________________ cm/m — Determine the scale factor
(Divide the results of [a] by [b].)

d. ________________ cm — Measure the semi-major axis from the orbit.

e. ________________ m — Determine the semi-major axis in meters. (Divide the results of [d] by [c].)

f. ________________ m^3 — a^3 - Semi-major axis cubed
(Multiply the result from [e] by itself three times)

g. ________________ sec^2 — Multiply k times a^3.
(8.02×10^{-12} sec^2/m^3) X the result from [f].

h. ________________ sec — Determine the orbital period in seconds.
(Take the square root of the result from [g].)

i. ________________ hours — Determine the orbital period in hours.
(Divide the result from [h] by 3,600 sec/hr.)

6. Find the mass of the moon (in kilograms) using the Newtonian form of Kepler's third law. The third law is given by

$$P^2 = \frac{4\pi^2}{G} \frac{a^3}{(m + M)}$$

and

$$\frac{4\pi^2}{G} = 5.92 \times 10^{11} \frac{kg \cdot s^2}{m^3}$$

is constant (show your work below).