Jeremy Maniago

PHYS 454

Professor Hedberg

HW#2

# Question 1 – Prove Kepler’s second law (numerically)

a) The object chosen for this analysis is a comet orbiting the sun called Swift-Tuttle (109P). JPL Horizons [[1]](#one) was utilized to obtain vector and orbital element data for a time range from June 15th, 1737, to August 23rd, 1862 – about 125 years. According to Nasa’s small-body lookup database [[2]](#two), the eccentricity of Swift-Tuttle’s orbit is around 0.96, which is highly eccentric. Some of the Swift-Tuttle’s orbital elements are shown in **Table 1**.

|  |  |
| --- | --- |
| Swift-Tuttle Orbital Elements | |
| Eccentricity | 0.96 |
| Inclination (w.r.t. the ecliptic plane) [deg] | 113.45 |
| Perihelion [AU] | 0.96 |
| Aphelion [AU] | 51.22 |

Table 1: Orbital Elements of Swift-Tuttle's orbit.

With the range and true anomalies of the Swift-Tuttle at specific time times obtained from JPL Horizons, we can pick a smaller time range to prove Kepler’s 2nd Law, which is that “A line connecting a planet to the Sun sweeps out equal areas in equal times”. In this case, instead of a planet we will be using a comet. A date range of 240 months (20 years) was chosen. The equation to numerically estimate the swept area of an ellipse is given by **Equation 1**.

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

where is the final range (distance from comet to sun), is the initial range, and is the difference in the true anomalies from the initial and final time, which can be defined as:

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

The first 20-year range was from 1739 to 1759 (starting and ending on February 2nd), and the swept area was approximated to **4931.61 AU2**. The second 20-year range was from 1829 to 1849 (starting and ending on February 2nd), and the swept area was approximated to **4967.84 AU2**. These values are, although varying by 31 AU2 in calculated area, are close enough to prove Kepler’s 2nd Law. The percent error from the second and first area is a mere **0.73%**. Reasons for this error is due to data uncertainties and the nature of numerical methods being only approximations of a true value.

b) **Figure 1** shows four plots. The first plot (top left) shows Swift-Tuttle’s orbit around the sun with earth’s orbit as reference. The second plot (top right) is a zoomed in version of the first plot to better see earth’s orbit compared to Swift-Tuttle’s. We can see that the perihelion of the comet is in fact a little smaller than the radius of earth’s orbit, which is 1 AU. The third plot (bottom left) represents the calculated swept area for the first-time range, and the fourth plot (bottom right) represents the calculated swept area for the second-time range. The reason for plotting the orbit in 3D is because the inclination of Swift-Tuttle’s orbit is off of the Sun-Earth ecliptic plane. The full orbit of the comet cannot be seen in just two dimensions.

A screenshot of a graph

Description automatically generated

Figure 1: Plots of Swift-Tuttle's orbit. The view angle is defined as 20 deg elevation, 55 deg azimuth, and 0 deg roll.

# Question 2 – Balls of Gas

# Question 3 – Eclipse

a)

# References

[1]

[2]

[3]

[4] Source Code -