Homework 3

AE 402 – Fall 2021

Due: Tuesday, November 30, 2021 @ 11pm CT

Starred problem (*) to be complete by 4-credit students only.

Round all answers to 3 decimal places and type into Gradescope. Upload all figures and code into Gradecope.

Problem 1

Use Lambert's problem to solve for the Δv required to send a spacecraft from Earth to impact the asteroid Apophis. The spacecraft will depart Earth on **May 1, 2024** and arrive at Apophis on **June 15, 2025**. The time-of-flight is **410 days**. Use the JPL horizons website to query the position and velocity of Earth and Apophis on those days with respect to the solar system barycenter (SSB). When solving for the Lambert transfer consider only the gravity from the Sun and neglect the gravity of the Earth and Apophis. This type of mission is known as a kinetic impactor and is one approach for moving asteroids that are on a collision course with the Earth.

Problem 2

Compute the total Δv required to send a spacecraft a from a geocentric circular orbit of $7000\ \mathrm{km}$ radius to geocentric circular orbit of $105000\ \mathrm{km}$ radius using a Hohmann transfer. Repeat the Δv computation using a bi-elliptic transfer where apogee of the intermediate orbit is $210000\ \mathrm{km}$. Which approach requires less Δv? At what value, to the nearest km, of apogee of the intermediate orbit does the other approach require the least Δv?

Problem 3*

A spacecraft is Mars bound on a Hohmann transfer from Earth. Upon reaching Mars the spacecraft will perform an un-powered flyby with a periapse altitude of 100 km above the surface of Mars. Compute the half turn angle $\left(\frac{\delta}{2}\right)$ for this flyby. Repeat the computation for flyby altitudes ranging from 100 km to 5000 km, in intervals of 100 km, above the surface of Mars. Create a plot of altitude vs $\frac{\delta}{2}$. Repeat the computations for Jupiter, using the same flyby altitudes, and plot the curve on the same figure. Which planet causes the spacecraft to turn through a greater angle during the flyby. Assume that all the planets are in circular orbits around the Sun. Use the following data.

Gravitational Parameters

$\mu_{\mathrm{Earth}} = 398600\ \mathrm{km}^3/\mathrm{s}^2$
$\mu_{\mathrm{Mars}} = 42828.37\ \mathrm{km}^3/\mathrm{s}^2$
$\mu_{\mathrm{Jupiter}} = 126686534\ \mathrm{km}^3/\mathrm{s}^2$
$\mu_{\mathrm{Sun}} = 1.32712440018 \times 10^{11}\ \mathrm{km}^3/\mathrm{s}^2$

Planetary orbit radii

$r_{\mathrm{Earth}} = 1\ \mathrm{AU}$
$r_{\mathrm{Mars}} = 1.524\ \mathrm{AU}$
$r_{\mathrm{Jupiter}} = 5.2\ \mathrm{AU}$

Planetary radii

$R_{\mathrm{Earth}} = 6378.137\ \mathrm{km}$
$R_{\mathrm{Mars}} = 3396.2\ \mathrm{km}$
$R_{\mathrm{Jupiter}} = 71491\ \mathrm{km}$

$AU = 149.6 \times 10^6\ \mathrm{km}$