IIT Hyderabad

Assignment 1

Ready, One. Two. Three... Let them roll

Submitted by:
Abhishek Ghosh
ME21BTECH11001
ME5060: Spacecraft Dynamics and Control
Mechanical Engineering
20.02.2025

Submitted to:
Dr. Vishnu Unni

Problem A

1 Simulate the orbital motion of the Earth around the Sun. [5 Points]

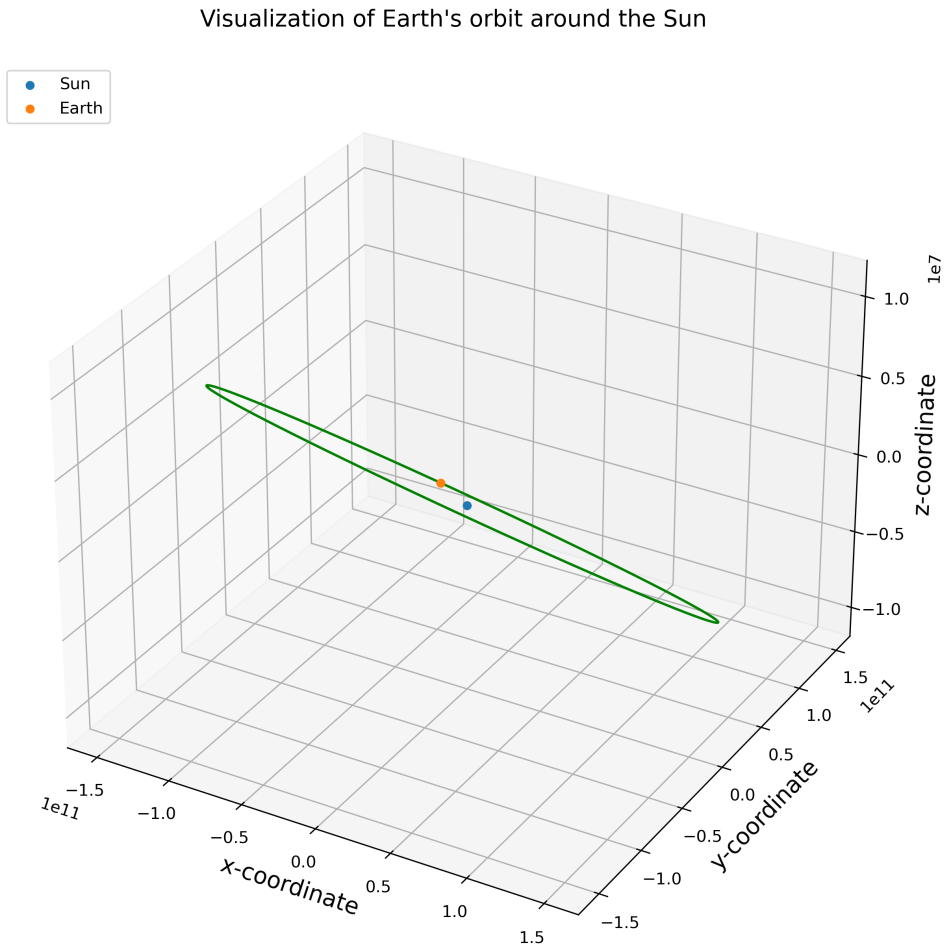

Figure 1: Earth's Orbital Motion around the Sun

Steps:

- Retrieve the initial conditions for Earth's position and velocity relative to the Sun using JPL Horizons.
- Use numerical integration (e.g., Runge-Kutta method or other ODE solvers) to simulate Earth's orbit based on Newton's law of gravitation.
- Plot the orbit of Earth around the Sun over one year to verify a stable elliptical orbit.

The **Time period** is found out to be 31557600.0 seconds which is approximately **365.25 days**.

2 What happens to the Earth's orbital motion if you add the rest of the planets (without Earth's moon) vs. if you add just the Earth's moon? [5 points]

2.1 Earth's orbital motion under influence of Moon

- The Moon creates a more localized effect because it directly influences Earth's barycenter (center of mass of the Earth-Moon system)
- The **Time period** is found out to be 31563118.906505264 seconds which is approximately **365.32 days**.

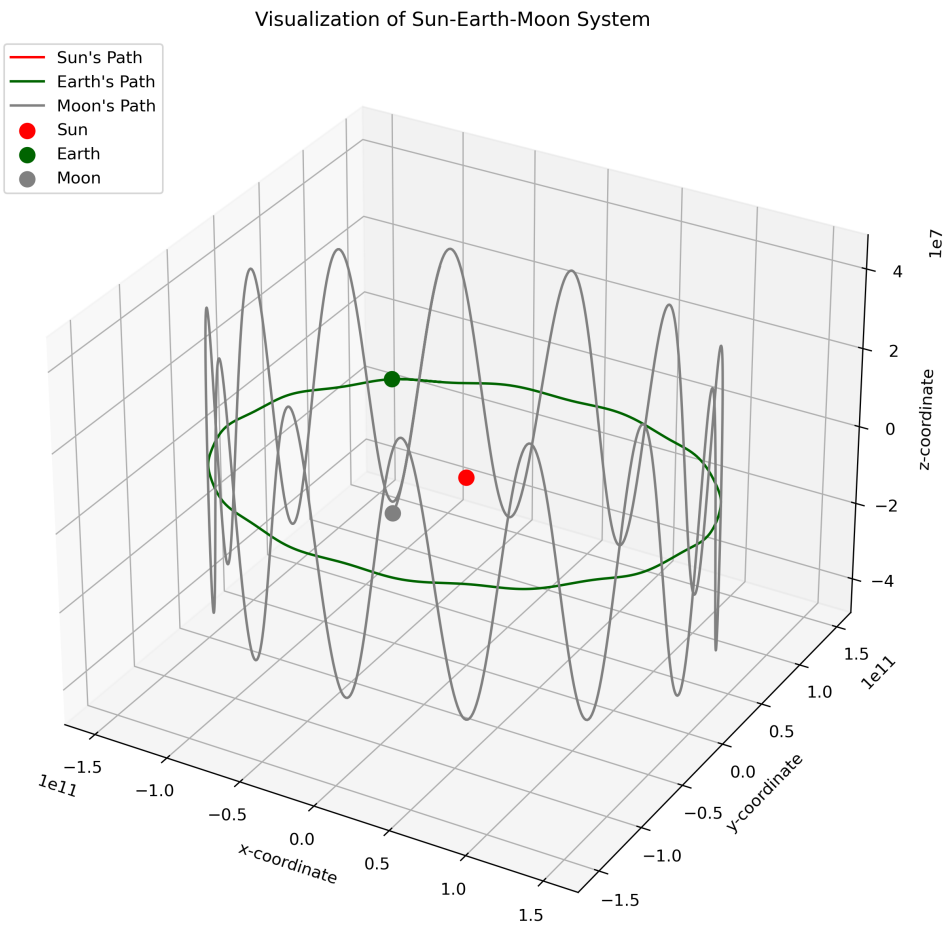

Figure 2: Earth's Orbital Motion around the Sun under the influence of Moon.

2.2 Earth's orbital motion under influence of other Planets (without the Earth's Moon)

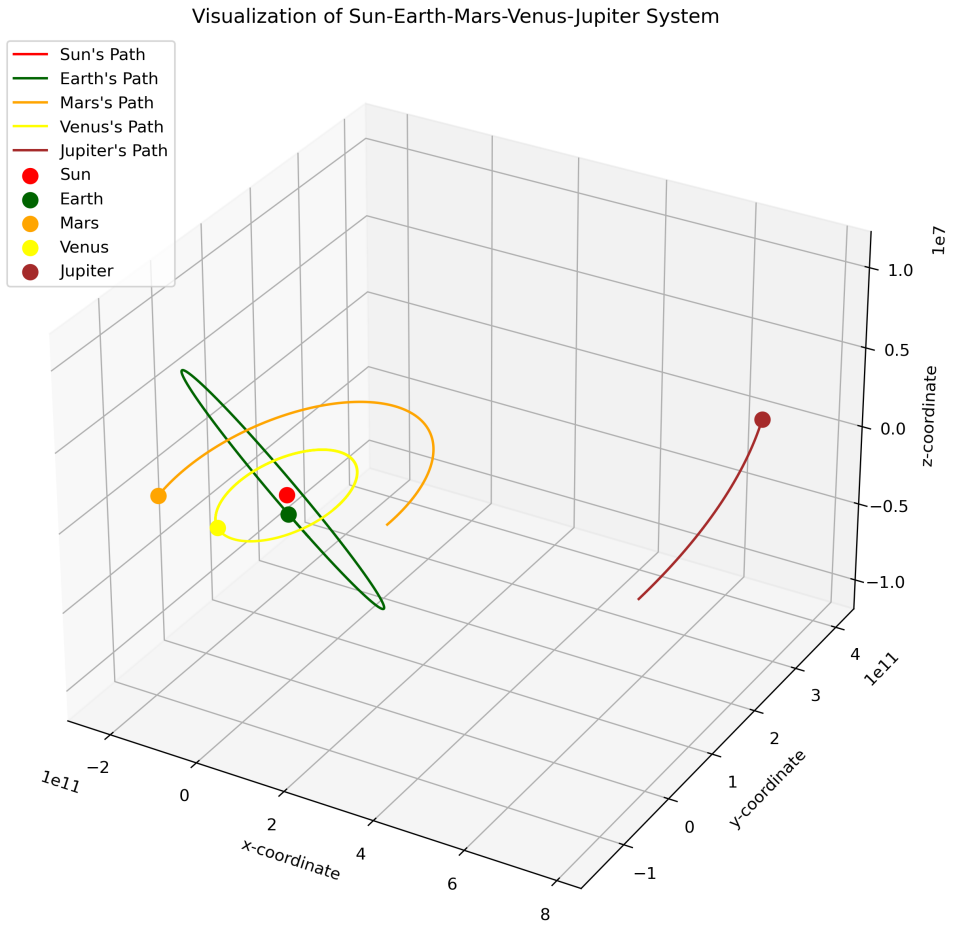

Figure 3: Earth's Orbital Motion around the Sun under the influence of other planets.

- The gravitational forces from other planets affect Earth's motion slightly (perturbations).
- Only four planets Earth, Mars Venus and Jupiter are shown and not all 8 because starting from Jupiter, the 5th planet, the orbital radius becomes very large (greater than 5 times that of Earth). Including them in the animation will make the inner planets nearly invisible.
- The **Time period** is found out to be 32536000.0 seconds which is approximately **376.57 days**.
- The time period difference between the above two cases is 972881.1 seconds which is approximately 270.25 hours.

3 Plot the motion of the moon and earth on an earth-centered inertial and earth-fixed F.O.R.s [5 points]

3.1 Earth Centered Inertial Frame

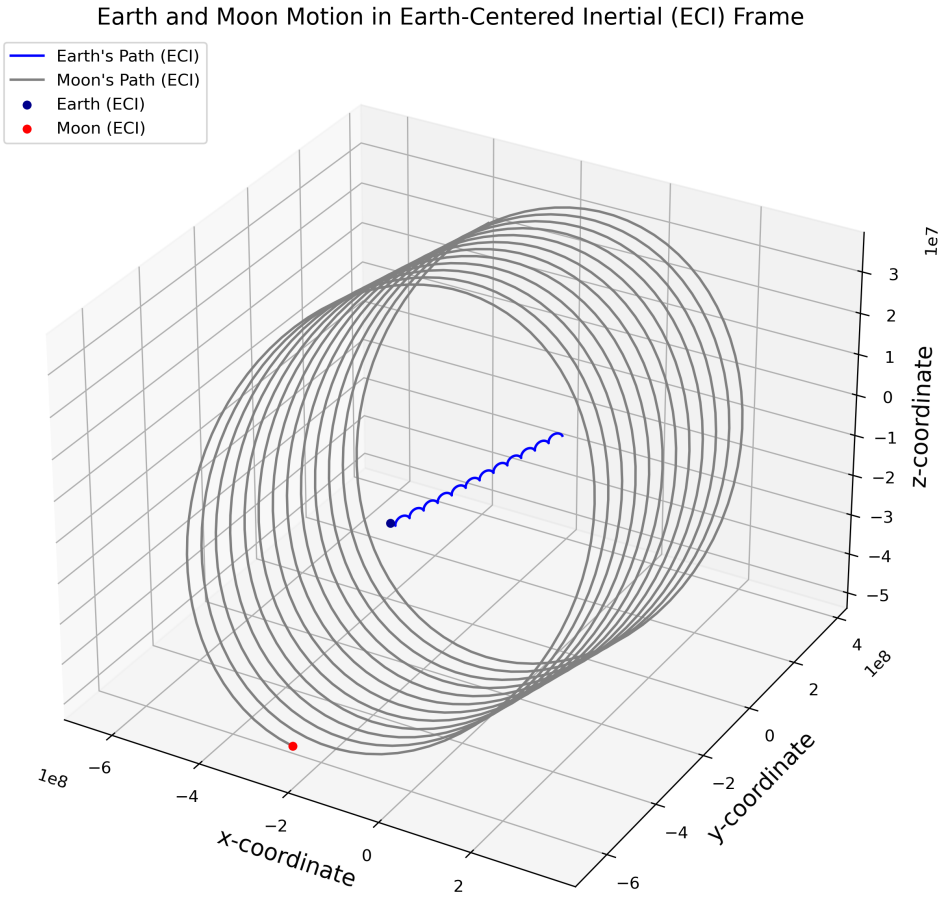

Figure 4: Earth Centered Inertial Frame

- In an Earth-centered inertial (ECI) frame, the Earth is stationary, and both the Moon and the Earth's orbit appear as trajectories relative to fixed space coordinates
- The **Time period** is found out to be 10690.177010949861 seconds .

3.2 Earth Fixed Frame

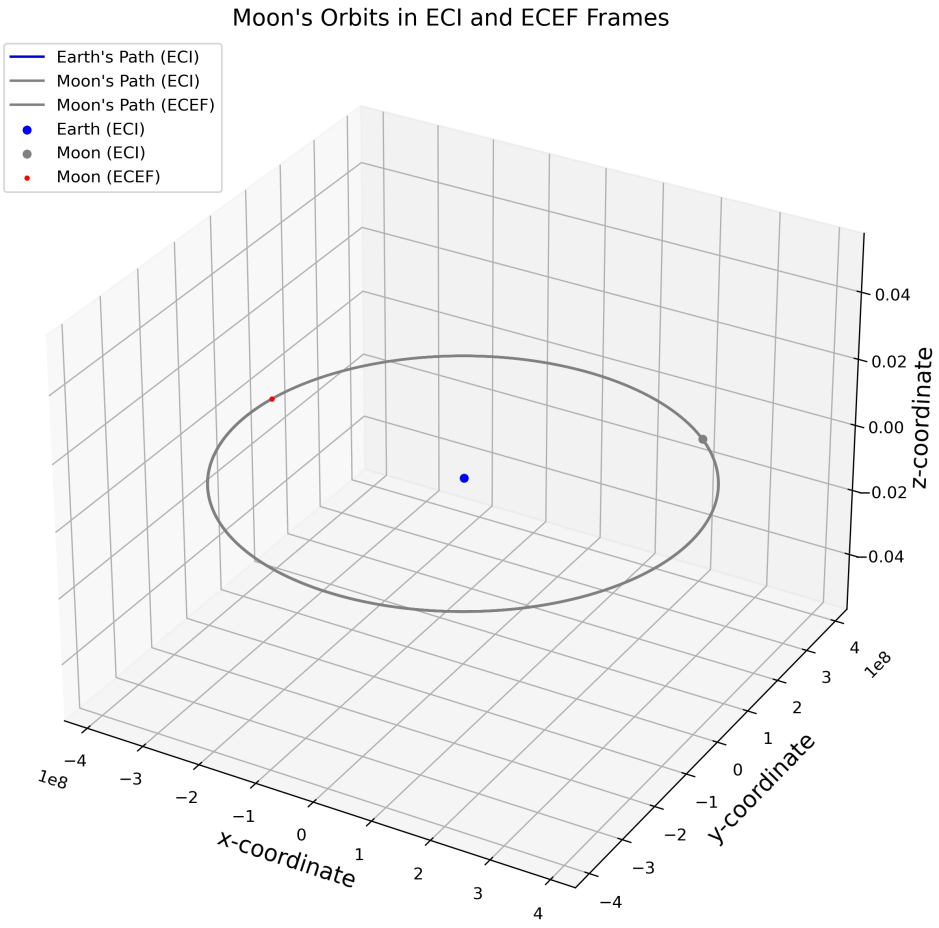

Figure 5: Earth Fixed Frame

- In an Earth-fixed frame, the Earth rotates with time, so the Moon's path appears relative to a rotating Earth surface.
- The **Time period** is found out to be 89413.501350135 seconds .

4 For any given location on the surface of Earth, find all the times of the year when the moon is visible along with Jupiter within 10 degrees of the line of sight of the moon. [5 Points]

- This requires determining when the Moon and Jupiter are in close angular proximity in the sky and visible from the observer's location.
- Moon and Jupiter are visible at the following times (in hours): [0.00000000e+00 2.77786586e-01 5.55573173e-01 ... 8.74138830e+03 8.74166609e+03 8.74194387e+03]

References

1 All values are taken from the JPL's Horizon

2 The code used to generate plots is in the ME21BTECH11001.ipynb file.

3 The photos and GIFs for the animation are in the Photo and Gif Folder.

4 The code has been generated with the help of Chat GPT 4-o model and the following has been used as references

- https://archive.ph/pbTlLselection-923.0-929.29
- https://medium.com/analytics-vidhya/simulating-the-solar-system-with-under-100-lines-of-python-code-5c53b3039fc6
- https://gist.github.com/benrules2/220d56ea6fe9a85a4d762128b11adfba