SESA2024 Astronautics

University of Southampton

Chapter 5: Mission Analysis

Lecture 2 – Kepler's Laws

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Overview of lecture 2

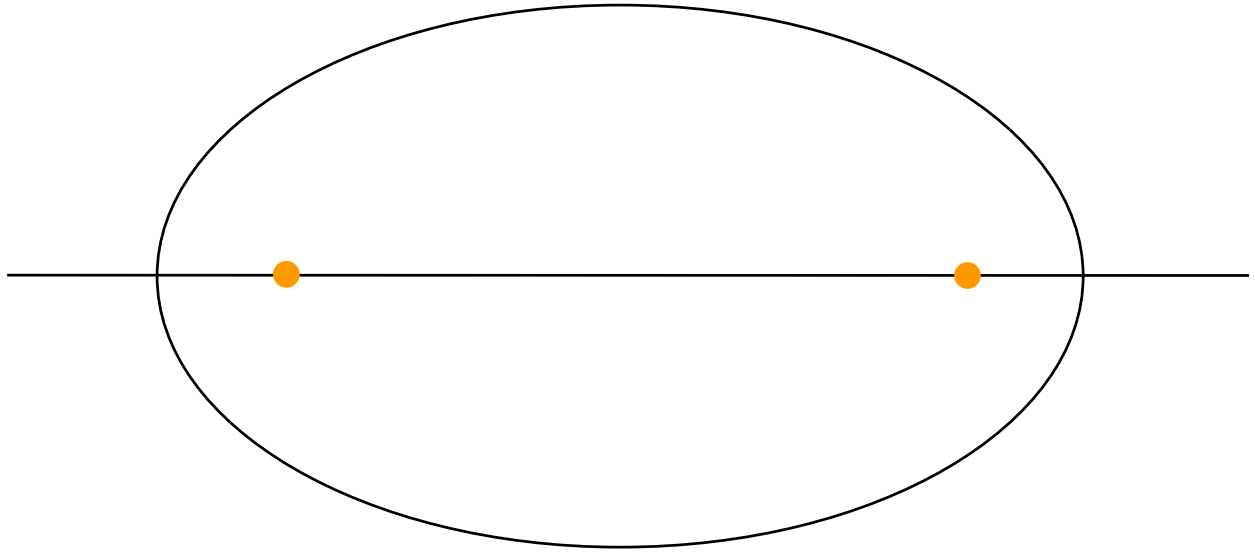
- This is a short lecture focused on:
  1. Kepler's Laws of Planetary Motion:
     - These are three laws identified by Kepler using observations of
       - The shape of planetary orbits
       - The nature of the motion of planets around the Sun
       - The time taken for planets to move around the Sun
  2. How Kepler's Laws became the basis for the modern, mathematical understanding of orbital motion

Kepler's laws of planetary motion

- Johannes Kepler
  - December 1571 – November 1630
  - A key figure in the 17th-century scientific revolution, best known for his laws of planetary motion, and his books Astronomia nova, Harmonices Mundi, and Epitome Astronomiae Copernicanae.
  - *"I demonstrate by means of philosophy that the earth is round, and is inhabited on all sides; that it is insignificantly small, and is borne through the stars"*

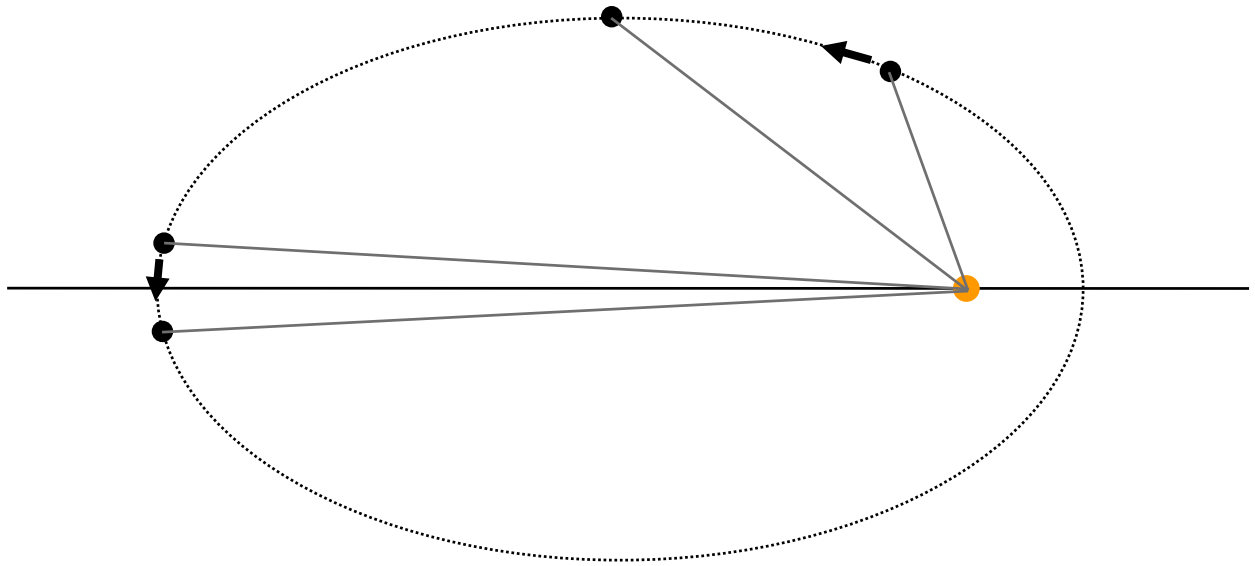
Kepler's laws of planetary motion

1. The orbit of each planet is an ellipse with the Sun at one focus (1609)



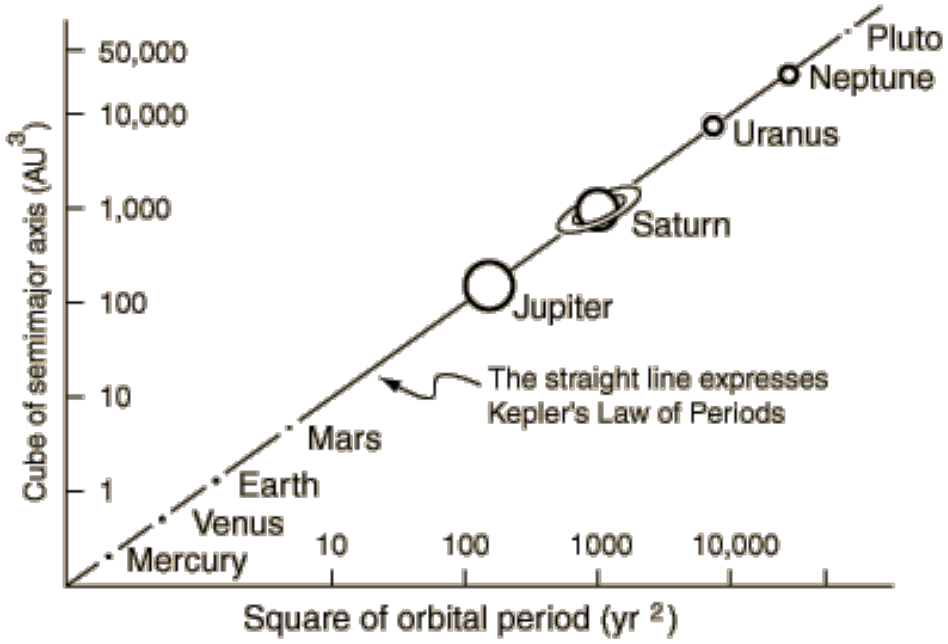
Kepler's laws of planetary motion

2. The line joining the planet to the Sun sweeps out equal areas in equal times (1609)



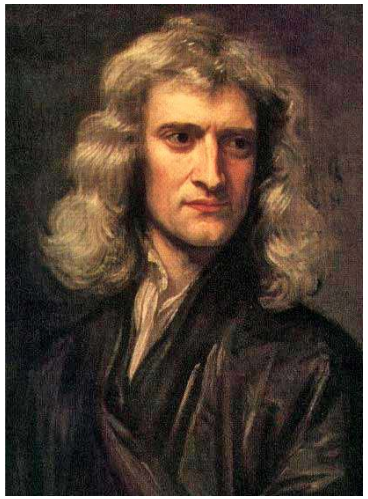
Kepler's laws of planetary motion

3. The square of the period of the planet is proportional to the cube of its mean distance from the Sun (1619)



Kepler's laws of planetary motion

- Kepler's laws originated from observations of the solar system
- In his book 'Philosophiae Naturalis Principia Mathematica' (1687) Isaac Newton established that Kepler's laws follow mathematically from his Law of Universal Gravitation and his Laws of Motion
  - He proved using calculus that orbits are elliptical if the gravitational force is inverse square



We will look at Kepler's 1st Law initially: we will first understand how to describe an ellipse using mathematics (the ellipse equation)