

Elements of Celestial Mechanics (Elementi di Meccanica Celeste) (2025/2026, second semester)

Teacher: Giacomo Tommei

1 Introduction

Celestial Mechanics is a branch of Mathematics devoted to the study of the motion of the celestial bodies on the basis of the law of gravitation of Newton. Newton's theory of universal gravitation resulted from experimental and observational facts: the observational facts were those discussed in the three Kepler laws; the experimental facts were those reported by Galileo in his book *Discourses Relating to Two New Sciences*. The basis of Newton theory came from the idea that the force keeping the Moon in orbit around the Earth is the same that, on Earth, commands the fall of the bodies.

The interesting thing is that Newton's gravitation theory allows the construction of sets of ordinary differential equations whose solutions are the time laws of motion of the bodies. If the bodies are just two the problem is integrable, while if the number of bodies is greater than two is not.

After a brief review of some concepts of dynamical systems and analytical mechanics (including an introduction to Hamiltonian theory), the course will start studying in detail the gravitational 2-body problem (formulation as a system of ODE, reduction to Kepler problem, resolution by prime integrals, Lagrangian and Hamiltonian approaches). Then we will move on to the circular restricted 3-body problem, studying the Jacobi integral and the admissible regions of motion of the third body; some astrodynamics applications will be shown. As third argument we will discuss the problem of tides and tidal evolution in the solar system. In the final part we will deal with the problem of orbit determination describing some methods of initial orbit determination and introducing the least squares method to compute a nominal orbit.

2 Practical Information

The course will last 48 hours, and it will take place in the second semester. The exam will be a written examination consisting of exercises and description of the topics discussed during the lectures.

The prerequisites for this course are the skills acquired in the first/second year courses in Mathematics, Physics or Aerospace Engineering.

Whoever is interested in knowing more about this course can contact me via e-mail: **giacomo.tommei@unipi.it** .