Course syllabus

Kaos
Chaos

FMFN05, 7,5 credits, A (Second Cycle)

Valid for: 2023/24
Faculty: Faculty of Engineering, LTH
Decided by: PLED F/Pi
Date of Decision: 2023-04-18

General Information

Language of instruction: The course will be given in English on demand

Aim

The aim of the course is to introduce chaotic systems and different approaches towards non-linear problems. Several conceptual tools and examples to approach and interpret the non-linear are provided to the student in order to understand complex systems and their eventually chaotic nature. The course shows the pervasive nature of these concepts and gives a possibility to reflect over the fascinating phenomena which may show up in chaotic systems. The abstract and theoretical nature of chaos theory is declined in practical and concrete concepts. For example, strange attractors will highlight the importance of fractal geometry, in order to discuss the posibility that the Solar system is unstable over a longer time scale. The fascinating universality of chaotic behaviour across science and technology will deliver a precious lesson on the beauty and impact of mathematical investigation of phenomena.

Learning outcomes

Knowledge and understanding
For a passing grade the student must

- be able to decribe the system conditions leading to chaotic and regular behaviour, respectively
- be able to account for and interpret mathematical methods used to analyse chaotic systems
- be able to describe why it is useful to introduce dimensions which are not integer.

Competences and skills
For a passing grade the student must

- be able to apply mathematical methods used for the description of non-linear systems
- be able to analyse the time development of a system and be able to determine if the system is chaotic or regular
- be able to determine which mathematical models are appropriate in different situations
- be able to determine the dimension of simple fractals.

Judgement and approach
For a passing grade the student must

- be able to demonstrate an understanding of possibilities and limitations of methods that are covered in the course
- be able to find properties of the phase space of simple non-linear problems and discuss the chaotic nature of such systems
- be able to demonstrate a methodology to approach the study of complex problems in the project setting
- be able to interpret and assess information in the field of the course from sources in addition to the course material, e.g. scientific articles and advanced literature.

Contents

The course gives an introduction to non-linear and chaotic systems, i.e. non-linear systems that are deterministic but with a time development which is not predictable over longer periods. The study of non-linear systems is an application of mathematics with profound impact on our understanding of physical, biological, computer, and complex systems in general. The course will introduce the mathematical methods needed to study discrete and continuous non-linear systems. Then, it will provide examples of non-linear systems in science and technology.

Temporally discrete systems

- Feigenbaum’s theory of branching
- Dependence on initial values
- Fractal geometry with various applications
- Different definitons of dimensions
- Cellular Automata

Continuous systems

- Systems of differential equations
- Phase space and the Poincaré section
- Lyapunov exponents and strange attractors
- Coupled oscillators and frequency locking
- Dissipative systems.

After the basic discrete and continuous representations, students must choose an additional study module. Different study modules can be offered according to need and availability, including the application of chaos theory in physics, or biology, economics. One of this study modules is always offered.

Conservative systems and the KAM theory

- Hamilton's formalism
- Integrable systems, billiards
- Area-preserving maps

- Chaotic motion in the Solar system.

Examination details

Grading scale: TH - (U,3,4,5) - (Fail, Three, Four, Five)
Assessment: Examination takes place through a written examination at the end of the course, and the written report of the group project.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Parts
Code: 0109. **Name:** Chaos.
Credits: 6. **Grading scale:** TH. **Assessment:** Written exam. **Contents:** The theoretical part of the course.
Code: 0209. **Name:** Project.
Credits: 1,5. **Grading scale:** UG. **Assessment:** Presentaion of project. **Contents:** Project

Admission

Assumed prior knowledge: Elementary mathematics and mechanics.
The number of participants is limited to: No
The course overlaps following course/s: FMF090, FMF092

Reading list

- Ohlén, G, Åberg, S, Östborn, P: Chaos, Compendium. Lund 2006.

Contact and other information

Course coordinator: Andrea Idini, andrea.idini@matfys.lth.se
Course homepage: http://www.matfys.lth.se/education/FMFN05