

COM-502

**Dynamical system theory for engineers**

Thiran Patrick

Cursus	Sem.	Type
Computational science and Engineering	MA2, MA4	Opt.
Computational science and engineering minor	E	Opt.
Computer science	MA2, MA4	Opt.
Cybersecurity	MA2, MA4	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Mechanical engineering	MA2, MA4	Opt.
Neuro-X minor	E	Opt.
Neuro-X	MA2, MA4	Opt.
Robotics, Control and Intelligent Systems		Opt.
SC master EPFL	MA2, MA4	Opt.
Systems Engineering minor	E	Opt.

Language of teaching	English
Credits	6
Session	Summer
Semester	Spring
Exam	Written
Workload	180h
Weeks	14
<b>Hours</b>	<b>4 weekly</b>
Lecture	3 weekly
Exercises	1 weekly
<b>Number of positions</b>	

**Remark**

Cours biennal

**Summary**

Linear and nonlinear dynamical systems are found in all fields of science and engineering. After a short review of linear system theory, the class will explain and develop the main tools for the qualitative analysis of nonlinear systems, both in discrete-time and continuous-time.

**Content**

- **Introduction:** Dynamics of linear and non linear systems. Definitions; Unicity of a solution; Limit Sets, Attractors.
- **Linear Systems:** Solutions; Stability of autonomous systems, Geometrical analysis, connection with frequency domain analysis.
- **Nonlinear Systems:** Solutions; Examples. Large-scale notions of stability (Lyapunov functions). Hamiltonian systems, gradient systems. Small-scale notions of stability (Linearization; stability and basin of attraction of an equilibrium point, stability of periodic solutions, Floquet Multipliers). Graphical methods for the analysis of low-dimensional systems. Introduction to structural stability, Bifurcation theory. Introduction to chaotic systems (Lyapunov exponents); time permitting: a review of tools of measure theory to compute Lyapunov exponents.
- The class is methodology-driven. It may present some limited examples of applications, but it is not application-driven.

**Keywords**

Dynamical Systems, Attractors, Equilibrium point, Limit Cycles, Stability, Lyapunov Functions, Bifurcations, Lyapunov exponents.

**Learning Prerequisites****Required courses**

- Linear algebra (MATH 111 or equivalent).
- Analysis I, II, III (MATH 101, 106, 203 or equivalent).
- Circuits & Systems II (EE 205 or equivalent) or a Systems & Signals class (MICRO 310/311 or

equivalent).

### Recommended courses

- A first-year Probability class, such as MATH-232, MATH-231, MATH-234(b), MATH-234(c), or equivalent.
- Analysis IV (MATH 207 or equivalent)

### Important concepts to start the course

- Linear Algebra (vector spaces, matrix operations, including inversion and eigendecomposition).
- Calculus (linear ordinary differential equations; Fourier, Laplace and z-Transforms).
- Basic notions of topology.
- Basic notions of probability.

### Learning Outcomes

By the end of the course, the student must be able to:

- Analyze a linear or nonlinear dynamical system.
- Anticipate the asymptotic behavior of a dynamical system.
- Assess / Evaluate the stability of a dynamical system.
- Identify the type of solutions of a dynamical system.
- Analyze a linear or nonlinear dynamical system
- Anticipate the asymptotic behavior of a dynamical system
- Assess / Evaluate the stability of a dynamical system
- Identify the type of solutions of a dynamical system

### Teaching methods

- Lectures (blackboard), 2h per week
- Exercise session, 1h per week

### Expected student activities

Exercises in class and at home (paper and pencil, and Matlab)

### Assessment methods

1. Mid-term 20% (conditionally on the Covid situation allowing for it to be taken at EPFL).
2. Final exam 80%

### Supervision

Office hours	Yes
Assistants	Yes
Forum	Yes

### Resources

#### Bibliography

Course notes; textbooks given as reference on the moodle page of the course.

**Notes/Handbook**

Course notes, exercises and solutions provided on the moodle page of the course.

**Moodle Link**

- <https://go.epfl.ch/COM-502>

**Prerequisite for**

Classes using methods from dynamical systems.