**EPFL**

COM-502 | **Dynamical system theory for engineers**

Thiran Patrick

| Cursus | Sem. | Type |
|---|---|---|
| Biocomputing minor | H | Opt. |
| Bioengineering | MA1, MA3 | Opt. |
| Computational Neurosciences minor | H | Opt. |
| Computational science and Engineering | MA1, MA3 | Opt. |
| Computer science | MA1, MA3 | Opt. |
| Cybersecurity | MA1 | Opt. |
| Life Sciences Engineering | MA1 | Opt. |
| SC master EPFL | MA1, MA3 | Opt. |
| Sciences du vivant | MA1, MA3 | Opt. |
| Systems Engineering minor | H | Opt. |

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|---|---|
| Language of teaching | English |
| Credits | 4 |
| Session | Winter |
| Semester | Fall |
| Exam | Written |
| Workload | 120h |
| Weeks | 14 |
| **Hours** | **3 weekly** |
| Courses | 2 weekly |
| Exercises | 1 weekly |
| **Number of positions** | |

## 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). Hamltionian 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).
- 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 Probabilty 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 sytem.

**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%
2. Final exam 80%

**Supervision**

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|---|---|
| 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**

- http://moodle.epfl.ch/course/view.php?id=303

**Prerequisite for**

Classes using methods from dynamical systems.