

## Modeling Complex Systems (C004453)

**Course size** *(nominal values; actual values may depend on programme)*

**Credits 6.0** **Study time 180 h**

**Course offerings in academic year 2025-2026**

A (semester 2) English Gent

**Lecturers in academic year 2025-2026**

De Buyl, Sophie	VUB	lecturer-in-charge
Gelens, Lendert	VUB	co-lecturer

**Offered in the following programmes in 2025-2026**

Master of Science in Teaching in Science and Technology (main subject Physics and Astronomy)	6	A
Master of Science in Physics and Astronomy	6	A
Master of Science in Physics and Astronomy	6	A

**Teaching languages**

English

**Keywords**

**Position of the course**

<https://caliweb.vub.be/?page=course-offer&id=004928&anchor=1&target=pr&year=2223&language=en&output=html>

The overall objective of this course is to be able to analyze dynamical systems using geometrical methods on the phase space. This includes carrying out linear stability, bifurcation and phase plane analyses. We will first focus on one and two dimensional systems. Chaotic phenomena in physical systems will be described with two classical examples: the Lorentz strange attractor and the logistic map. Solving problems and reading literature related to the course material is also foreseen.

**Contents**

- General introduction about linear versus nonlinear dynamics.
- Dynamical systems with one variable.
- Bifurcations in one variable systems: saddle-node, cusp, transcritical and imperfect bifurcations.
- Bifurcations on the circle, synchronisation.
- Linear dynamics with two variables: classification of the fixed points (saddle, node, center, degenerate).
- Nonlinear dynamics with two variables: phase space analysis, reversibility, Lyapunov function, theory of the index.
- Limit cycles: relaxation oscillations, singular perturbation.
- Chaos: Lorentz model and analysis.
- One dimensional maps: bifurcations, period doubling and intermittency route to chaos, universality.
- Fractals: self-similarity, fractal dimension.
- Strange attractors: stretching and folding, baker's map, Hénon map.
- Pattern formation.

**Initial competences**

**Final competences**

To be able to analyze dynamical systems using geometrical methods on the phase space. This includes carrying out linear stability, bifurcation and phase plane analyses.

#### **Conditions for credit contract**

Access to this course unit via a credit contract is determined after successful competences assessment

#### **Conditions for exam contract**

This course unit cannot be taken via an exam contract

#### **Teaching methods**

Seminar, Lecture, Independent work

#### **Study material**

None

#### **References**

#### **Course content-related study coaching**

#### **Assessment moments**

end-of-term assessment

#### **Examination methods in case of periodic assessment during the first examination period**

Oral assessment, Written assessment

#### **Examination methods in case of periodic assessment during the second examination period**

Oral assessment, Written assessment

#### **Examination methods in case of permanent assessment**

#### **Possibilities of retake in case of permanent assessment**

not applicable

#### **Extra information on the examination methods**

The final grade is composed based on the following categories:

Oral Exam determines 60% of the final mark.

PRAC Presentation determines 40% of the final mark.

Within the Oral Exam category, the following assignments need to be completed:

Written exam with a relative weight of 60 which comprises 60% of the final mark. This is a mid-term test.

Note: oral exam with a written preparation (theory and exercises)

Within the PRAC Presentation category, the following assignments need to be completed:

Presentation with a relative weight of 40 which comprises 40% of the final mark.

Note: presentation of group work (during the classes)

#### **Calculation of the examination mark**

- oral exam with a written preparation (theory and exercises) for 60% of the final grade.
- presentation of a group project (during one of the classes) for 40% of the final grade.