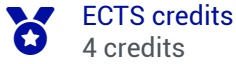


Modelling for BME



In brief

➤ **Course language:** English

Presentation

Prerequisites

Linear Algebra

Differential equations

Numerical Methods

Convex Optimization

Basics of systems dynamics (Training M1 CSE)

Learning objectives

By the end of this course, students will:

- master the concepts and tools required for modelling light propagation in biological tissues, with a focus on identifying key physical parameters and their relationship to tissue molecular composition.
- understand how electromagnetic waves, from X-rays to infrared light, interact with biological media, and how measurements can be used to infer intrinsic properties such as absorption and scattering, linked to specific molecules.
- Formulate and solve forward problems describing light transport, as well as inverse problems aimed at recovering tissue parameters from data. Applications include X-ray tomography and diffuse optical tomography, highlighting both linear and non-linear approaches.

- Apply dimensional analysis (Buckingham π theorem) to simplify complex governing equations and identify essential physical parameters in biomechanics.
- Become familiar with complex dynamics features of living systems (ecosystems, micro-organisms, etc) and relate them to the basics of statistical physics and non-linear physics concepts (such as phase transitions, bifurcation, stability, self-organization, percolation...)

Description of the programme

1- Modelling, Forward and Inverse Problems (Martin RODRIGUEZ-VEGA)

This course is organised into three main parts

Modelling and forward problems : Formulation of light propagation models in biological tissues and introduction to forward problems. Practical sessions focus on implementing and solving these models using numerical schemes in Python.

Linear inverse problems : Reformulation of imaging problems, such as X-ray tomography, into linear inverse problems, followed by the study and comparison of several solution approaches.

Non-linear inverse problems : Introduction to non-linear formulations through diffuse optical tomography, expressed as a convex optimization problem and solved using iterative methods.

By emphasizing a limited set of essential principles within a unified framework, the course provides efficient tools for addressing complex imaging and parameter estimation problems in biomedical optics.

2- Scaling and Self-Similarity (Martin BRANDENBOURGER)

This course provides the analytical tools to construct rapid, low-order models that highlight the fundamental physics and quantitative behavior of a system. By mastering dimensional analysis and the Buckingham π theorem, you will learn to derive dimensionless ratios that predict biomechanical scaling laws such as bone strength and muscle force, while enabling the simplification of complex equations derived from first principles, such as the Navier-Stokes equations.

3- Complex living systems modeling (J. FADE & F. SCHWANDER)

This course will be the occasion to revisit basics of statistical physics and non-linear physics concepts (such as phase transitions, bifurcation, stability, self-organization, percolation...) and show how they can appear in the modeling of complex dynamics of living systems, starting from ecosystems to micro-biology or gene evolution. These concepts will be illustrated through numerical simulations.

Teaching team

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Total des heures

CM	Master class	36h
TP	Practical work	24h
		12h

Useful info

Name responsible for EU

Lead Instructor

Julien Fade

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