UCLouvain

linma2720 — Mathematical modelling of physical systems

2026

5.00 credits	30.0 h + 22.5 h	Q2

Teacher(s)	Crevecoeur Frédéric ;Delvenne Jean-Charles ;
Language :	English > French-friendly
Place of the course	Louvain-la-Neuve
Prerequisites	Basic notions of physics and applied mathematics given in Bachelor of Engineering's programme. A master course on dynamical systems such as LINMA2370 or LINMA2361 is useful.
Main themes	The focus is mainly set on the mathematical modeling of physical systems described by partial differential equations. Multi- We develop methodologies to model adequately complex physical systems. The topics may include: • Dimensionality analysis. • Networks of dynamical systems. • Model reduction: how to make complex models simple. • Brownian motion and stochastic differential equations (Fokker-Planck equations, Itô calculus). • Random networks and matrices. These concepts and models can be applied to model real-world processes and systems for example: stochastic models of human movements (upper limb or saccadic eye movements with noise in neural command), physiological time series (fractional Gaussian noise in gait time series, Hurst exponent), stochastic diffusion of information in networks (epidemics, adoption, opinion dynamics), models of ecological diversity (May's theorem), models of computing devices (electronic, DNA computing, etc.).
Learning outcomes	**At the end of this learning unit, the student is able to :** Contribution of the course to the program objectives : • AA1.1, AA1.2, AA1.3 • AA2.1 • AA5.2, AA5.3 The main objective of this course is to familiarise the student with mathematical modelling of continuous physical systems. **Disciplinary learning outcomes** • Be able to formulate a mathematical model of a complex physical system using the principles of physics and appropriate behavioural models. • Be able to highlight the dominant physical mechanisms, and choose which phenomena to model and in what degree of detail, and model the various inherent uncertainties (including using random models). • Gain an in-depth understanding of the different approaches to mathematical modelling of a complex problem. • As part of the project, be able to analyse a sophisticated mathematical model critically and in detail. **Cross-curricular learning outcomes** • Critical bibliographical research and initial discovery of scientific literature. • Effective written and oral presentation of a complex technical project.
Evaluation methods	Evaluation: oral exam (open book; 50% of final mark), project (written report + 20 minute presentation to fellow students; 50% of final mark)
Teaching methods	Ex cathedra courses developing the methodologies on examples, projects on real cases, written exam.
Content	Topics covered include: (i) dimensional analysis (Buckingham "Pi" Theorem, similarity solutions, scaling), (ii) perturbation methods (regular and singular perturbations, boundary layers, matched asymptotic expansions, multi-scale analysis), (iii) generic topic of diffusion processes (random walk and Brownian motion, diffusion equation, Fick's constitutive equation, Einstein and Langevin approaches), (iv) stochastic calculus and Fokker-Planck equation for Markov processes (Wiener process, Itô calculus, equivalence between stochastic differential equation and Fokker-Planck equation, numerical methods), (v) illustration of recent developments: micro-macro modeling of polymer dynamics (kinetic theory of polymer solutions, associated Fokker-Planck equation, closure approximations and derivation of constitutive equations, numerical solution of Fokker-Planck equation in configuration spaces of high dimension).

Inline resources	Various optional documents (slides, bibliographical and web references) are gathered at http://moodleucl.uclouvain.be/course/view.php?id=874
Bibliography	• M. H. Holmes (2009) Introduction to the Foundations of Applied Mathematics • E.J. Hinch (1991) Perturbation Methods • H.C. Öttinger (1996) Stochastic Processes in Polymeric Fluids
Other infos	--
Faculty or entity in charge	MAP

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Master [120] in Mathematical Engineering	MAP2M	5		