Syllabus

Subject

Subject / Group	11002 - Stochastic processes / 1
Degree	Master's in Physics of Complex Systems
Credits	3
Period	1st semester
Language of instruction	English

Professors

Lecturers	**Office hours for students**					
	Starting time	**Finishing time**	**Day**	**Start date**	**End date**	**Office / Building**
Raúl Toral Garcés *Responsible* rtg803@uib.es	10:00	11:00	Monday	07/10/2019	25/06/2020	Despatx 212, edifici IFISC
Pere Colet Rafecas	10:00	11:00	Tuesday	01/10/2019	31/07/2020	Despatx 210 IFISC, Edifici Instituts Universitaris d'Investigació,

Context

This is one of the compulsory courses of the Structural Module of the Master in Physics of Complex Systems. It provides a solid background on stochastic processes that will be used elsewhere in the master, in particular in the course on Stochastic Simulation Methods which runs in parallel with this one.

In all areas of science, there are situations in which the description of the system under study requires the consideration of probability theory. There are many examples of this intrinsic randomness, from the production of complex molecules inside the cell, to the stock market dynamics and many others in different disciplines. That does not mean that a mathematical description of the system is not possible, but that an element of randomness has to be introduced in the theory from the very beginning. Despite the general belief that physical theories are always deterministic and predictive, the truth is that Statistical and Nonlinear Physics is a well established discipline that incorporates randomness in the description of a physical system at a very fundamental level. Since the pioneering works of Ludwig Boltzmann, Albert Einstein, Paul Langevin and many others, it has become clear that macroscopic laws can emerge from a probabilistic framework that takes into account the unavoidable elements of randomness, arising from our lack of knowledge of the exact microscopic description, including all forces between particles and their initial conditions. After more than a century and a half of expertise, we have learnt that beyond the predictions of the average values of the outcome of an experiment, the fluctuations around the mean values and the probability distribution of the possible outcomes bear much information about the microscopic mechanisms that underlie the process under scrutiny. In these cases, a deterministic analysis of the occurring processes may be inadequate or lacking of the relevant information sought. In this context, Master, Langevin and Fokker-Planck equations are extensively used mathematical tools to deal with such situations. In this course, we introduce the theory behind these descriptions.

Requirements

Recommended

It is recommended that the student has a basic knowledge on probability theory and statistics.

Skills

Specific

* E2: Development and optimal application of numerical algorithms for the simulation of complex systems
* E6: To understand and to model processes subject to fluctuations

Generic

* TG1: To be able to describe, both mathematically and physically, complex systems in different situations
* TG2: To acquire the capacity to develop a complete research plan covering from the bibliographic research and strategy to the conclusions
* TG3: To write and describe rigorously the research process and present the conclusions to an expert audience
* TG6: To acquire high power computation skills and advanced numerical methods capabilities in applications to problems in the context of complex systems

Basic

* You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

Content

Range of topics

1. Introduction
   Basic Concepts. Brownian motion. Einstein Description. Langevin description.

2. Markov processes
   Definition. The Chapman-Kolmogorov equation. Random walk. Poisson process. Dichotomous noise. Stable distributions. Lévy flights.

3. Stochastic differential equations.
   Wiener process. Continuous limit. White noise. Ito and Stratonovich interpretations. Ornstein-Uhlenbeck process.

4. Fokker-Planck equations

Derivation starting from the stochastic differential equation. Novikov Theorem. Stationary solution. Potential case. Detailed balance.

5. Introduction to Master equations
   Two-state systems. Birth and death processes. The particle and the occupation numbers points of view. The step operator. The general form of a master equation. Examples.
6. The generating-function method
   The generating-function method to solve master equations. The steady state. Large deviations. Examples.
7. Approximate methods of solutions of the master equation
   The mean-field theory. Beyond mean-field: Gaussian approximation. The Fokker-Planck equation approximation.
8. Van Kampen's expansion of the master equation
   The singular expansion in a large parameter. Approaches through the master equation and through the equations for the moments. Examples.
9. Constructive effects induced by fluctuations
   Time allowing, one or two seminars will be given at the end of the course addressing some advanced topics such as: Stochatic resonance, coherence resonance and noisy precursors.

Teaching methodology

The methodology consists of lectures given by the professor which will include the theoretical concepts and selected applications. The students will have before hand the slides and the basic notes of the lectures available at UIB's Aula Digital, so that they can look at the material before the lecture. Methodology also includes assignments to be worked out by students and submitted in a written report.

In-class work activities (0.75 credits, 18.75 hours)

Modality	Name	Typ. Grp.	Description	Hours
Theory classes	Lectures	Large group (G)	Explanation of theoretical concepts and selected examples and exercises by the professor.	17
Assessment	Exam	Large group (G)	This exam is intended to evaluate the knowledge adquired by the students. It will contain theoretical questions and problems.	1.75

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Aula Digital platform.

Distance education tasks (2.25 credits, 56.25 hours)

Modality	Name	Description	Hours
Individual self-study	Study and understanding theoretical concepts	This activity aims at the understanding of the theoretical concepts and techniques explained in the lectures.	30.25
Individual self-study	Assignments	The student has to solve assigned exercises including the details of some derivations sketched in class and the applications of the theory to practical cases. The assignments have to be submitted in a written report.	26

Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

Student learning assessment

The evaluation of the subject will consist on a written exam (50% of the final grade) and the submission of periodic assignments (50% of the final grade)

Frau en elements d'avaluació

In accordance with article 33 of Regulation of academic studies, "regardless of the disciplinary procedure that may be followed against the offending student, the demonstrably fraudulent performance of any of the evaluation elements included in the teaching guides of the subjects will lead, at the discretion of the teacher, a undervaluation in the qualification that may involve the qualification of "suspense 0" in the annual evaluation of the subject".

Exam

Modality	Assessment
Technique	Objective tests **(retrievable)**
Description	This exam is intended to evaluate the knowledge adquired by the students. It will contain theoretical questions and problems.
Assessment criteria	Accuracy of the answers. Clarity and quality of the explanations.

Final grade percentage: 50%with a minimum grade of 4

Assignments

Modality	Individual self-study
Technique	Papers and projects **(non-retrievable)**
Description	The student has to solve assigned exercises including the details of some derivations sketched in class and the applications of the theory to practical cases. The assignments have to be submitted in a written report.
Assessment criteria	Accuracy of the results. Clarity and quality of the explanations and interpretation of the results. Quality of the written presentation.

Final grade percentage: 50%with a minimum grade of 5

Resources, bibliography and additional documentation

Besides the slides and notes of the course that will be made available to students through UIB's Aula Digital, we recommend the following bibliography:

Basic bibliography

R. Toral and P. Colet, "Stochastic Numerical Methods", Wiley (2014). Chapters 6 and 8.
N.G. Van Kampen, “Stochastic Processes in Physics and Chemistry”, 3rd edition, North Holland (2007).

Complementary bibliography

C.W. Gardiner, “Handbook of Stochastic Methods”, 3rd edition, Springer (2004).
H. Risken, “The Fokker-Planck Equation”, 2nd edition 3rd printing, Springer (1996).