Mathematical Modeling of Systems in Natural Sciences

Course guide

Last update: December 2020

1. General information

Name of the course	Mathematical Modeling of Systems in Natural Sciences
Code	11010040
Type of course	Compulsory
Number of credits	2
Type of credit	A
Hours of weekly work with direct teacher accompaniment	64
Weekly hours of independent student work	32
Prerequisites	(11310005) LINEAR ALGEBRA, (11310002) COMPUTER PROGRAMMING , (11310009) PROBABILITY "OR" (new) PROBABILITY AND STATISTICS 2, (11310040) MODELING OF DYNAMICAL SYSTEMS
Corequisites	None
Schedule	
Area Leader	David Andrade
Classroom	Lovelace

2. Instructor information and teaching assistant

Name professor	David Andrade
Professional profile	PhD in Applied Mathematics. Research Areas: Water Waves, Fluid Dynamics and Differential Equations
Institutional email	davideu.andrade@urosario.edu.co

Website (optional)	
Name of teaching assistant	
Professional profile	
Institutional email	
Place and hours of student attention:	Cabal, Office 402.
Web page, Skype or other means (optional)	

3. Summary and purposes of the course

One of the most active fields in the area of Applied Mathematics is what is known as mathematical modeling. In it, as its name suggests, mathematical models are created to analyze and study problems in different empirical fields. The objective of this course is to introduce the theoretical foundations and some essential tools of mathematical modeling when applied to biological, chemical and physical processes. Theoretical content will be always supported with examples of applications in each of these areas. Furthermore, to ensure a comprehensive learning experience, some fundamentals aspects in Biology, Chemistry and Physics will be taught to guarantee that modeled processes presented throughout the course are fully understood.

In this course, the subject will be approached from the perspective of applications (models), introducing the motivations and applied and practical contexts and then presenting the classical theoretical tools.

4. Fundamental Topics

Topic 1: What is mathematical modeling?
Topic 2: Foundations: Dimensional analysis, scaling, approximation and validation of models.
Topic 3: Mathematical modeling of discrete processes.
Topic 4: Mathematical modeling of continuous processes using ODEs.
Topic 5: Multidimensional models and partial differential equations.
Topic 6: Mathematical modeling with delayed differential equations.
Topic 7: Mathematical modeling with stochastic differential equations.

5. Expected Learning Results (ELR)

1. Understand the mathematical foundations of methods in modeling in natural sciences.
2. Develop an advanced knowledge of Matlab in problems related to mathematical modeling in natural sciences.
3. Learn fundamentals of relevant topics in Biology, Chemistry and Physics related to mathematical modeling in these areas.
4. Identify problems in which mathematical modeling tools find application.
5. Draw conclusions as a result of using mathematical modeling methods in relation to the problems studied.
6. Have a first encounter with recent academic developments related to mathematical modeling in natural sciences.

6. Course modality

Mixed mode: Some students will be present at the classroom and others will connect remotely from their homes or locations outside the University.

7. Learning strategies

1. Workshops
2. Homework
3. Lectures
4. Projects

8. Evaluations

Topic	Activities	Percentage
1-3	Examination 1	20
4-5	Examination/ example sheet 2	25
6-7	Examination/ example sheet 3	25
End of semester	Final project	30

9. Programming of activities

Date (Session)	Topic	Description of the activity	Independent work of the student (recommended exercises)	Resources that support the activity
Session 1	1: Introduction	Introduction		[1, chap. 1] [2, ch. 1]
Session 2	2: Dimensional analysis, scaling, approximation and validation.	Dimensional analysis	[2, Ex 2.3, **2.5, 2.7**, 2.13, **2.14**, 2.16, 2.19, **2.23**]	[2, Ch. 2]
Session 3		Scaling	[2, Ex 3.6, 3.12, 3.13,3.15, **3.18**, **3.19**, 3.26, 3.28, 3.31, 3.33, 3.34, **3.35**, 3.36, **3.37**]	[2, Ch. 3]
Session 4		Approximation and validation	[2, Ex **4.4**, 4.10, 4.16, 4.19, **4.22**, 4.25, 4.28, **4.31**, **4.35**, 4.36, **4.50 4.51**]	[2, ch. 4]
Session 5		Problems session		[2, ch. 2,3,4]
Session 6	Basic concepts in Cell Biology			
Session 7	Basic concepts in Ecology			
Session 8	3: Mathematical modeling of discrete processes. Models in Ecology and Physics.	Difference equations	[1, ch. 2. Ex. **3,4,7,11,12,13, 19,21,29**]	[1, ch. 2]
Session 9		Discrete linear models		[1, ch. 2]
Session 10		Discrete nonlinear models		[1, ch. 2]
Session 11		Problems session		[1, ch. 2]
Session 12	Examination 1			
Session	Basic concepts in Nuclear and Organic Chemistry			

13				
Session 14	4: Mathematical modeling of continuous processes using ODEs. Models in Chemistry, Epidemiology, Physics, Pharmacology	Model design	[1, ch. 3. Ex. **1, 5, 6, 9, 18, 20,** 23, 31**, 36,** 50] [2, Ex 5.5, 5.11, **5.12,** 5.31, 7.1, **7.8**, 7.21, **7.28, 7.32**]	[1, ch. 3]
Session 15		Dynamical systems and bifurcation analysis		[1, ch. 3]
Session 16		Exponential growth and decay		[2, ch. 5]
Session 17		Free vibrations		[2, ch. 7]
Session 18		Problems session		[1, ch. 3] [2, ch. 5, 7]
Session 19	5: Multidimensional models and PDEs. Models in Ecology, Physics and Cell Biology (cancer).	Diffusion models	[1, ch. 4. Ex. **1, 2, 4, 6, 10, 11, 15**]	[1, ch. 4]
Session 20		Linear stability analysis		[1, ch. 4]
Session 21		Spatio-temporal models		[1, ch. 4]
Session 22		Problems session		[1, ch. 4]
Session 23	Examination 2			
Session 24	6: Mathematical modeling with delayed differential equations. Models in Cell Biology, Ecology and Organic Chemistry.	Delay differential equations.	[1, ch.5. Ex. **1, 2, 3, 5,6,8,14,16**]	[1, ch. 5]
Session 25		Linear stability analysis		[1, ch. 5]
Session 26		Models with delayed differential equations.		[1, ch. 5]
Session 27		Problems session		[1, ch. 5]
Session 28	7. Mathematical modeling with stochastic differential	Introduction to Stochastic Processes	[1, ch.6. Ex. **1,2,3,4,5,6,7,9**]	[1, Ch. 6]
Session 29		Introduction to Stochastic Calculus		[1, ch. 6]

Session 30	equations. Models in Ecology and Molecular Biology (cancer).	Models with stochastic differential equations		[1, ch. 6]
Session 31		Problems session		[1, ch. 6]
Session 32	Examination 3			

10. Key factors for success in this course

A series of actions are suggested below that can contribute significantly to the achievement of goals and consequently promote a successful experience in this course:

1. Plan and organize individual work time for the course

2. Organize the workplace and the studying materials

3. Have a study group, search for peer support

4. Cultivate discipline and constancy, work weekly, do not allow topics or work to accumulate

5. Constantly carry out a self-evaluation, determine if the actions carried out are productive or if, on the contrary, strategies should be changed

6. Attend the teacher's consultation hours, participate in class, never be left with doubts

7. Use the spaces designated for consultations and resolution of doubts (Gauss Room)

8. Provide spaces for to rest and mental hygiene, try to have good sleep habits

9. Keep in mind values such as honesty and sincerity at all times, in the end it is not just about passing an exam, it is about learning and acquiring knowledge. Fraud is a delusion

11. Bibliography and resources

[1] Mathematical Modeling: Models, Analysis and Applications. 1st Edition
Sandip Banerjee.
[2] Principles of Mathematical Modeling. 2nd Edition. Clive Dym Additional

12. References and supplementary resources

Modeling fluctuating populations. 1st Edition. RM Nisbet, WCS Gurney
Bertsekas, Tsitsiklis. Introduction to Probability. Second Edition, 2008.
Introduction To Stochastic Calculus with Applications (2nd Edition). F. Klebanner Operating

13. Course agreements

There will be no approximation of grades at the end of the semester. The grades will only be changed based on TIMELY claims within the time limits determined by the Academic Regulations. If for reasons of "force majeure" the student misses an examination or quiz, he / she must follow the regular procedure determined by the Academic Regulations to present a supplementary evaluation. There will be no informal agreements in this regard. No student will be exempted from any exam.

The partial exams will be carried out synchronously through the zoom platform, during the exam the student must have the camera turned on.

DISCIPLINARY PROCESSES-FRAUD IN EVALUATIONS

Taking into account the training-preventive and disciplinary regulations of the Universidad del Rosario, and the certainty that fraudulent actions go against the teaching and learning processes, any corrupt act linked to this subject will be notified to the corresponding academic secretariat so that the due disciplinary process begins. It is recommended that students read these regulations to know the reasons, procedures and consequences that this type of action may cause, as well as their rights and duties associated with this type of procedure. Zero tolerance for fraud

14. Respect and non-discrimination

If you have a disability, whether visible or not, and require some kind of support to be on an equal footing with other students, please inform your teacher so that Reasonable course adjustments can be made as soon as possible. Likewise, if you do not have the technological resources required for the development of the course, please inform the Academic Secretary of your program or the Student Office in a timely manner, so that your request can be met on time.

Remember that it is the duty of all people to respect the rights of those who are part of the Rosarista community. Any situation of harassment, sexual harassment, discrimination or bullying, whether in person or virtual, is unacceptable. Anyone who feels in any of these situations can report its occurrence by contacting the team of the Coordination of Psychology and Quality of Life of the Dean of the University Environment (Telephone or WhatsApp 322 2485756).