NATIONAL UNIVERSITY OF SAN MARCOS

FACULTY OF MATHEMATICAL SCIENCES

SYLLABUS

1. GENERAL INFORMATION

1.1 Course name	:	Mathematical Modeling
1.2 Code	:	MA361
1.3 Academic Program	:	Scientific Computing
1.4 Credits	:	4
1.5 Prerrequisites	:	MA325. Numerical Analysis II. (6^{th} Sem)
1.6 Type of Course	:	Mandatory
1.7 Area of Studies	:	Estudios Generales
1.8 Number of Weeks	:	16
1.9 Hours per week	:	2 HT; 4 HP;
1.10 Cycle	:	I
1.11 Learning modality	:	Face to face
1.12 Academic Period	:	2026-I
1.13 Semester Start Date	:	
1.14 Semester End Date	:	

2. PROFESSORS

Meetings after coordination with the professor

3. INTRODUCTION TO THE COURSE

This course introduces the fundamental principles of mathematical modeling to represent, analyze, and predict the behavior of systems in various areas such as science, engineering, and business. It emphasizes the formulation of models from real-world problems, their solution using mathematical and computational tools, and the critical interpretation of results. The course develops abstraction skills and the application of advanced mathematics to solve complex real-world problems.

4. GOALS

- Understand the fundamental principles and stages of the mathematical modeling process.
- Formulate mathematical models from concrete problems in different scientific and technological contexts.
- Apply analytical and numerical methods to solve the proposed models.
- Critically interpret simulation results and validate models with real data.
- Develop skills to effectively communicate models and their conclusions.

5. COMPETENCES

ABET-1) An ability to identify, formulate, and solve broadly defined technical or scientific problems by applying knowledge of mathematics and science and/or technical topics to areas relevant to the discipline. (Usage)

ABET-3) An ability to develop and conduct experiments or test hypotheses, analyze and interpret data, and use scientific judgment to draw conclusions. (Usage)

6. TOPICS

Unit 1: Mathematical Model Formulation (16 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Modeling process and cycle • Continuous vs. discrete models • Deterministic vs. stochastic models • Assumptions identification and simplification techniques • Dimensional analysis and scaling	• Describe the complete modeling cycle from problem definition to solution interpretation [Familiarity] • Classify models as continuous/discrete and deterministic/stochastic [Assessment] • Identify and justify appropriate assumptions for model simplification [Assessment] • Apply dimensional analysis to reduce complexity of physical models [Usage]
Readings : [**Giordano2013**], [**Lin2009**]	

Unit 2: Continuous Systems Simulation (16 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Ordinary Differential Equations (ODEs) models • Partial Differential Equations (PDEs) models • Finite difference methods for PDEs • Solver selection and implementation • Stiff systems and adaptive methods	• Formulate ODE and PDE models for physical systems [Usage] • Implement finite difference methods for simple PDEs [Usage] • Select appropriate numerical solvers for different types of ODEs/PDEs [Assessment] • Handle stiff systems using appropriate numerical methods [Usage]
Readings : [**Braun2013**], [**Giordano2013**]	

Unit 3: Discrete Systems Simulation (16 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Queueing theory and models • Cellular automata and agent-based models • Monte Carlo simulation methods • Markov chains and processes • Discrete-event simulation	• Formulate and analyze simple queueing models [Usage] • Implement cellular automata and agent-based simulations [Usage] • Apply Monte Carlo methods for probabilistic simulation [Usage] • Analyze Markov chains for state transitions and steady-state behavior [Assessment] • Design discrete-event simulations for system analysis [Usage]
Readings : [**Giordano2013**], [**Meerschaert2013**]	

Unit 4: Sensitivity Analysis and Robustness (16 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Local sensitivity analysis (partial derivatives) • Global sensitivity analysis (Sobol indices) • Morris method and screening techniques • Robustness analysis and worst-case scenarios • Uncertainty propagation	• Perform local sensitivity analysis using derivative-based methods [Usage] • Apply global sensitivity analysis techniques (e.g., Sobol indices) [Usage] • Use Morris method for factor screening [Usage] • Assess model robustness under parameter variations [Assessment] • Quantify uncertainty propagation through models [Assessment]
Readings : [**Banks2010**], [**Giordano2013**]	

Unit 5: Model Validation and Verification (16 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Verification: numerical code correctness • Validation: comparison with experimental data • Uncertainty Quantification (UQ) in models • Model calibration and parameter estimation • Goodness-of-fit tests and metrics	• Distinguish between verification and validation in modeling [Familiarity] • Apply verification techniques to ensure code correctness [Usage] • Validate models using experimental data and statistical tests [Usage] • Calibrate model parameters using optimization techniques [Usage] • Apply uncertainty quantification methods to assess model reliability [Usage]
Readings : [**Giordano2013**], [**Lin2009**], [**Meerschaert2013**]	

7. WORKPLAN

7.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

7.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

7.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

8. EVALUATION SYSTEM

********* EVALUATION MISSING ********

9. BASIC BIBLIOGRAPHY