UNIVERSIDAD DE CASTILLA - LA MANCHA

GUÍA DOCENTE

1. General information

Course:	MATHEMATICAL MODELING IN CIVIL ENGINEERING	**Code:**	310800
Type:	CORE COURSE	**ECTS credits:**	9
Degree:	2343 - MASTERS DEGREE PROGRAMME IN ENGINEERING OF ROADS, CANALS AND PORTS	**Academic year:**	2019-20
Center:	603 - E.T.S. CIVIL ENGINEERS OF CR	**Group(s):**	20
Year:	1	**Duration:**	First semester
Main language:	English	**Second language:**	Spanish
Use of additional languages:		**English Friendly:**	N
Web site:		**Bilingual:**	N

Lecturer: **GABRIEL FERNANDEZ CALVO** - Group(s): **20**

Building/Office	**Department**	**Phone number**	**Email**	**Office hours**
Politecnico 2-D31	MATEMÁTICAS	6218	gabriel.fernandez@uclm.es	Please contact professor to appoint the date of the tutorial meeting/Contactar con el profesor para acordar fecha y hora de tutoría

2. Pre-Requisites

The following prerequisites are essential or highly recommended in order for the student to follow, without significant conceptual gaps, the contents of the course:

- Knowledge of single variable and multiple variable calculus (both differential and integral). This is essential.
- Knowledge of how to solve linear systems and acquaintance with elementary linear algebra properties. This is essential.
- Knowledge of basic analytical methods to solve elementary differential equations (both ordinary and partial). This is essential.
- Knowledge of basic interpolation and approximation techniques for functions and data. Highly recommended.
- Familiarity with MATLAB software. Highly recommended. Other programming languages oriented to numerical computing are also recommended (e.g. Python, Octave, Mathematica, etc).
- Acquaintance with fundamental equations and models arising in Mechanics of Materials, Continuous Media and Hydrology. Highly recommended.

3. Justification in the curriculum, relation to other subjects and to the profession

Nowadays, nearly all engineering companies and firms worldwide utilise modelling software to deal with projects, from small ones to big ones. Civil engineering students at the master level should be able not only to acquire the ability to use those complex (and very often expensive) programs but also to understand the underlying conceptual elements that make up those programs. Moreover, developing the skills to construct mathematical models (from simple to very technical ones) that can solve problems posed in a non-mathematical fashion, specially within the professional engineering scenario, can make a big difference between just a competent engineer and a truly *super-cruncher* engineer. It is frequently heard that in the professional context most civil engineers only employ a very basic knowledge of mathematics. While in most routine situations it is not necessary to have a great deal of mathematical knowledge to solve civil engineering problems (one may resort to well-known rules of thumb or to the use of the previously mentioned specific software, etc), having a sound background in mathematical modelling capabilities can make a huge impact when the time comes to really find both creative an innovative solutions to new and challenging problems.

The aim of this course is to provide the necessary tools to master-level students in order to acquire and develop mathematical modelling abilities useful for the professional civil engineering. We will start from elementary numerical methods (some of which were already studied during the Degree of Civil Engineering) and then move on to more advanced techniques to solve problems which, quite often, will be proposed in a non-mathematical context and with minimal information. Our modelling software of choice will be MATLAB, although other numerically-oriented software such as Python, Octave or Mathematica can be used as well. It is also worth mentioning that part of the contents of this course will be very useful in other master courses such as Continuum Mechanics and Materials Science, Coastal Engineering, Geotechnical Engineering, Hydraulic Works and Hydroelectric Exploitation, Transport Economy and, specially relevant for the Final Master Thesis. The far reaching goal is that every student, when given suitable practical scenarios, should be able to become proficient in constructing his/her own mathematical models and to solve them by means of the studied methods and techniques or even new ones developed by him/herself if required.

4. Degree competences achieved in this course

Course competences

Code	Description
AFC1	Ability to address and solve advanced mathematical engineering problems, from problem solving to formulation development and implementation in a computer program. In particular, the ability to formulate, program and apply advanced analytical and numerical models for calculation, design, planning and management, as well as the ability to interpret the results obtained, in the context of civil engineering.
CB06	Possess and understand knowledge that provides a basis or opportunity to be original in the development and / or application of ideas,

often in a research context

CB07	Apply the achieved knowledge and ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the area of study
CB09	Know how to communicate the conclusions and their supported knowledge and ultimate reasons to specialized and non-specialized audiences in a clear and unambiguous way
CB10	Have the learning skills which allow to continue studying in a self-directed or autonomous way
G01	Scientific-technical and methodological capacity for the continuous recycling of knowledge and the exercise of the professional functions of consultancy, analysis, design, calculation, project, planning, leadership, management, construction, maintenance, conservation and exploitation in the fields of civil engineering.
G17	Adequate knowledge of the scientific and technological aspects of mathematical, analytical and numerical methods of engineering, fluid mechanics, mechanics of continuous means, structural calculations, ground engineering, maritime engineering, water resources and linear works.
G18	Ability to participate in research projects and scientific and technological collaborations within its thematic area, in interdisciplinary contexts and, where appropriate, with a high knowledge transfer component.
G19	Knowledge of the latest developments and applications of technology to civil engineering in all its fields, as well as its new challenges.
G21	Ability to apply optimization tools to aid decision making, as well as to discern exploitation proposals compatible with the constraints and peculiarities of the built infrastructure.
G25	Ability to identify, measure, enunciate, analyse, diagnose and scientifically and technically describe a civil engineering problem
G27	Ability to communicate in a second language.
G28	Ability to work in an international context.
G29	Management capacity and teamwork.

5. Objectives or Learning Outcomes

Course learning outcomes

Description

Reinforcement of the students' deductive reasoning capacity.

Students solve basic problems of optimization and optimal control that arise in the planning and management of civil engineering.

Increase in the students' capacity for abstraction.

Students develop and program codes to implement the numerical methods studied to solve ordinary and/or partial differential equations that occur in the field of civil engineering.

Students address computationally intensive problems efficiently.

Students use software platforms to numerically address problems arising in the field of civil engineering.

Students can use estimation techniques for quantities and associated errors.

Students mathematically formulate and quantitatively solve a problem involving (ordinary and/or partial) differential equations using analytical techniques and/or numerical methods.

6. Units / Contents

Unit 1: Introduction to Mathematical Modelling in Civil Engineering

Unit 2: Introduction to Platforms for Advanced Numerical Computation: MATLAB

Unit 3: Review of Basic Numerical Methods

Unit 4: Numerical Solution of Ordinary Differential Equations

Unit 5: Numerical Solution of Partial Differential Equations

Unit 6: Optimization Methods in Civil Engineering

7. Activities, Units/Modules and Methodology

Training Activity	Methodology	Related Competences (only degrees before RD 822/2021)	ECTS	Hours	As	Com	R	Description
Class Attendance (theory) [ON-SITE]	Lectures	AFC1 CB06 CB07 CB09 CB10 G01 G17 G18 G19 G21 G25 G27 G28 G29	1.28	32	N	-	-	The topics covered in the course will be presented in the classroom through transparencies/blackboard. Notes and bibliographic excerpts will be made available in the Campus Virtual.
Problem solving and/or case studies [ON-SITE]	Project/Problem Based Learning (PBL)	AFC1 CB06 CB07 CB09 CB10 G01 G17 G18 G19 G21 G25 G27 G28 G29	0.56	14	Y	N	N	Following every lecture (with a typical duration of an hour), problem sets will be proposed to the students to be solved during the class. These sessions are at the heart of the course since they will provide the necessary skills in order to assimilate the contents of the course. Students are encouraged to actively participate in these sessions by presenting to the class partial/full solutions to the attempted problems.
								Another key aspect of this course is learning to develop both small and medium-size programs to solve computational problems using the studied numerical methods. Students may bring their

Computer room practice [ON-SITE]	Project/Problem Based Learning (PBL)	AFC1 CB06 CB07 CB09 CB10 G01 G17 G18 G19 G21 G25 G27 G28 G29	0.72	18	Y	Y	N	own laptops to the computer sessions, which will take place after completing each lesson (the specific dates will be announced in advance). Students will learn how to use at least one programming environment: preferentially MATLAB. Open source environments, such as Python, Maxima or Octave will also be accepted if the students are proficient in their use, although less support will be provided. During these computer sessions, a computational problem will be proposed. This problem will be solved either individually or in small teams (the modality will be announced in advance). The students are expected to significantly contribute to the solution and to interact with the professor.
Final test [ON-SITE]	Assessment tests	CB06 CB07 CB09 G01 G17 G18 G19 G21 G25 G27 G28 G29	0.16	4	Y	Y	Y	Students will have two opportunities to pass the course: the Ordinary and the Extraordinary calls. The exam, in any of these calls, will have the same structure: it will consist of a questionnaire, with short problems to be chosen by the student, followed by three-four full-development problems to be completed within 4 hours. Any of these exams will be global and, therefore, will include all the contents of the course. Since the exams will involve problem solving skills it is advised that students attend regularly to the problem solving sessions during the course.
Practicum and practical activities report writing or preparation [OFF-SITE]	Self-study	AFC1 CB06 CB07 CB09 CB10 G01 G17 G18 G19 G21 G25 G27 G28 G29	2.4	60	N	-	-	
Study and Exam Preparation [OFF-SITE]	Self-study	AFC1 CB06 CB07 CB09 CB10 G01 G17 G18 G19 G21 G25 G27 G28 G29	3.6	90	N	-	-	
On-line debates and forums [OFF-SITE]	Online Forums	CB06 CB07 CB09 G01 G17 G18 G19 G27 G28 G29	0.28	7	N	-	-	
		Total:	**9**	**225**				
		Total credits of in-class work: 2.72						**Total class time hours: 68**
		Total credits of out of class work: 6.28						**Total hours of out of class work: 157**

As: Assessable training activity
Com: Training activity of compulsory overcoming
R: Rescheduling training activity

8. Evaluation criteria and Grading System

	Grading System		
Evaluation System	**Face-to-Face**	**Self-Study Student**	**Description**
Final test	50.00%	0.00%	Ordinary/Extraordinary exams. The exam, in any of the Ordinary/Extraordinary calls, will have the same structure: it will consist of a short questionary followed by three-four full-development problems to be completed within 4 hours. Any of these exams will be global and, therefore, will include all the contents of the course. It is important to emphasise that a minimum grade will be required for the final exam (either the Ordinary/Extraordinary call) so as to take into account the assessment from the other activities as well. This minimum grade is 5/10. If this minimum grade is not reached in any of the two exams (Ordinary/Extraordinary), the student will not pass the course.
Assessment of problem solving and/or case studies	15.00%	0.00%	All students are encouraged and expected to actively participate in the problem solving sessions that will follow every lecture. Problem sets to be solved during class will be proposed to the students. Those providing and presenting to the rest of the class partial/full detailed answers will receive

			credit for their work in accordance with the difficulty level of the problem. Every student should furnish at least two such solutions (either partial/full) during the course to obtain a grade in this evaluation part.
Assessment of activities done in the computer labs	35.00%	0.00%	Computational problems will be posed to the students (to be solved individually or in a team). Most computational problems will have to be completed during the class. Students will have to submit their developed programs (via web upload through the Campus Virtual) for each assigned problem. The time allotted to solve these computational problems as well as their modality (individual/team) will be announced in advance. These sessions will not be repeated so that for every session missed by the student no credit will be given.
Total:	**100.00%**	**0.00%**	

Evaluation criteria for the final exam:

Students will have two opportunities to pass the course: the Ordinary and the Extraordinary calls. The exam, in any of these calls, will have the same structure: it will consist of a short questionnaire followed by three/four full-development problems to be completed within 4 hours. Any of these exams will be global and, therefore, will include all the contents of the entire course. Since the exams will involve problem solving skills it is advised that students attend regularly to both the problem solving sessions and the computational sessions during the course.

Specifications for the resit/retake exam:

Students will have two opportunities to pass the course: the Ordinary and the Extraordinary calls. The exam, in any of these calls, will have the same structure: it will consist of a short questionnaire followed by three/four full-development problems to be completed within 4 hours. Any of these exams will be global and, therefore, will include all the contents of the entire course. Since the exams will involve problem solving skills it is advised that students attend regularly to both the problem solving sessions and the computational sessions during the course.

9. Assignments, course calendar and important dates

Not related to the syllabus/contents	
Hours	**hours**

Unit 1 (de 6): Introduction to Mathematical Modelling in Civil Engineering

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	2
Problem solving and/or case studies [PRESENCIAL][Project/Problem Based Learning (PBL)]	1
Study and Exam Preparation [AUTÓNOMA][Self-study]	6
On-line debates and forums [AUTÓNOMA][Online Forums]	2

Unit 2 (de 6): Introduction to Platforms for Advanced Numerical Computation: MATLAB

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	1
Computer room practice [PRESENCIAL][Project/Problem Based Learning (PBL)]	4
Study and Exam Preparation [AUTÓNOMA][Self-study]	6

Unit 3 (de 6): Review of Basic Numerical Methods

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	8
Problem solving and/or case studies [PRESENCIAL][Project/Problem Based Learning (PBL)]	4
Computer room practice [PRESENCIAL][Project/Problem Based Learning (PBL)]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	18
Study and Exam Preparation [AUTÓNOMA][Self-study]	18
On-line debates and forums [AUTÓNOMA][Online Forums]	1

Unit 4 (de 6): Numerical Solution of Ordinary Differential Equations

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	6
Problem solving and/or case studies [PRESENCIAL][Project/Problem Based Learning (PBL)]	2
Computer room practice [PRESENCIAL][Project/Problem Based Learning (PBL)]	3
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	12
Study and Exam Preparation [AUTÓNOMA][Self-study]	12
On-line debates and forums [AUTÓNOMA][Online Forums]	1

Unit 5 (de 6): Numerical Solution of Partial Differential Equations

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	9
Problem solving and/or case studies [PRESENCIAL][Project/Problem Based Learning (PBL)]	4
Computer room practice [PRESENCIAL][Project/Problem Based Learning (PBL)]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	18
Study and Exam Preparation [AUTÓNOMA][Self-study]	24
On-line debates and forums [AUTÓNOMA][Online Forums]	1

Unit 6 (de 6): Optimization Methods in Civil Engineering

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	6
Problem solving and/or case studies [PRESENCIAL][Project/Problem Based Learning (PBL)]	3
Computer room practice [PRESENCIAL][Project/Problem Based Learning (PBL)]	3
Final test [PRESENCIAL][Assessment tests]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	12
Study and Exam Preparation [AUTÓNOMA][Self-study]	24

On-line debates and forums [AUTÓNOMA][Online Forums]	2

Global activity

Activities	hours
Class Attendance (theory) [PRESENCIAL][Lectures]	32
Problem solving and/or case studies [PRESENCIAL][Project/Problem Based Learning (PBL)]	14
Computer room practice [PRESENCIAL][Project/Problem Based Learning (PBL)]	18
Final test [PRESENCIAL][Assessment tests]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	60
Study and Exam Preparation [AUTÓNOMA][Self-study]	90
On-line debates and forums [AUTÓNOMA][Online Forums]	7
Total horas:	225

10. Bibliography and Sources

Author(s)	Title/Link	Publishing house	Citv	ISBN	Year	Description
Arora, J.S.	Introduction to Optimum Design	Fourth edition, Academic Press, Elsevier			2016	Lesson 6
Shankar, P.M.	Differential Equations: A Problem Solving Approach Based on MATLAB	CRC Press, Taylor & Francis Group			2018	Lesson 4
Attaway, S.	MATLAB: A Practical Introduction to Programming and Problem Solving	Fourth edition, Elsevier			2017	Lesson 2
Barnes, B., and Fulford, G.R.	Mathematical Modelling with Case Studies Using Maple and MATLAB	Third edition, CRC Press, Taylor & Francis Group			2015	Lesson 1
Belegundu, A.D., and Chadrupatla, T.R.	Optimization Concepts and Applications in Engineering	Second edition, Cambridge University Press			2011	Lesson 6
Bungartz, H.-J., Zimmer, S., Buchholz, M., and Pflüger, D.	Modeling and Simulation: An Application-Oriented Introduction	Springer-Verlag			2014	Lesson 1
Burden, R.L., Faires, J.D., and Burden, A.M.	Numerical Analysis	Tenth edition, Brooks/Cole Cengage Learning			2016	Lessons 3 and 4
Butcher, J.C.	Numerical Methods for Ordinary Differential Equations	Third edition, John Wiley & Sons			2016	Lesson 4
Chapman, S.J.	MATLAB Programming with Applications for Engineers	Cengage Learning			2013	Lesson 2
Chapra, S.C.	Applied Numerical Methods with MATLAB for Engineers and Scientists	Fourth edition, McGraw-Hill			2017	Lesson 2
Chapra, S.C., and Canale, R.P.	Numerical Methods for Engineers	Seventh edition, McGraw-Hill			2015	Lessons 3, 4, 5 and 6
Chaskalovic, J.	Mathematical and Numerical Methods for Partial Differential Equations: Applications for Engineering Sciences	Springer			2014	Lesson 5
Cheney, W., and Kincaid, D.	Numerical Mathematics and Computing	Seventh edition, Cengage Learning			2013	Lessons 3, 4, 5 and 6
Christensen, P.W., and Klarbring, A.	An Introduction to Structural Optimization	Springer			2009	Lesson 6
Epperson, J.F.	An Introduction to Numerical Methods and Analysis	John Wiley & Sons			2013	Lessons 3 and 4
Whiteley, J.	Finite Element Methods: A Practical Guide	Springer			2017	Lesson 5
Forst, W., and Hoffmann, D.	Optimization: Theory and Practice	Springer			2010	Lesson 6
Gander, W., Gander, M.J., and Kwok, F.	Scientific Computing: An Introduction using Maple and MATLAB	Fourth edition, Springer			2014	Lessons 3, 4 and 6
Gilat, A.	MATLAB: An Introduction with Applications	Fifth edition, John Wiley & Sons			2014	Lesson 2
Giordano, F.R., Fox, W.P., and Horton, S.B.	A First Course in Mathematical Modeling	Fifth edition, Brooks/Cole Cengage Learning			2014	Lesson 1
Griffiths, D.F., and Higham, D.J.	Numerical Methods for Ordinary Differential Equations: Initial Value Problems	Springer-Verlag			2010	Lesson 4
Heinz, S.	Mathematical Modeling	Springer-Verlag			2011	Lesson 1
	Introduction to Scientific					

Holmes, M.H.	Computing and Data Analysis	Springer		2016	Lessons 3, 4 and 6
Hritonenko, N., and Yatsenko, Y.	Mathematical Modeling in Economics, Ecology and the Environment	Springer		2013	Lesson 1
Imboden, D.M., and Pfenninger, S.	Introduction to Systems Analysis: Mathematical Modeling Natural Systems	Springer-Verlag		2013	Lesson 1
Khennane, A.	Introduction to Finite Element Analysis using MATLAB and Abaqus	CRC Press, Taylor & Francis Group		2013	Lesson 5
Kiusalaas, J.	Numerical Methods in Engineering with MATLAB	Third edition, Cambridge University Press		2016	Lessons 3, 4 and 6
Lindfield, G.R., and Penny, J.E.T.	Numerical Methods using MATLAB	Third Edition, Elsevier		2012	Lessons 3 and 6
Lyche, T., and Merrien, J.-L.	Exercises in Computational Mathematics with MATLAB	Springer-Verlag		2014	Lesson 2
Miller, G.	Numerical Analysis for Engineers and Scientists	Cambridge University Press		2014	Lesson 3
Moore, H.	MATLAB for Engineers	Third edition, Pearson Education		2012	Lesson 2
Pedregal, P.	Optimization and Approximation	Springer	978-3-319-64842-2	2017	Lesson 6
Quarteroni, A., Saleri, A., and Gervasio, P.	Scientific Computing with MATLAB and Octave	Fourth edition, Springer-Verlag		2014	Lessons 3 and 6
Rao, S.S.	Engineering Optimization: Theory and Practice	Fourth edition, John Wiley & Sons		2013	Lesson 6
Rao, S.S.	The Finite Element Method in Engineering	Fifth edition, McGraw-Hill		2011	Lesson 5
Sauer, T.	Numerical Analysis for Engineers and Scientists	Pearson Education		2012	Lessons 3, 4 and 5
Siauw, T., and Bayen, A.M.	An Introduction to MATLAB Programming and Numerical Methods for Engineers	Academic Press, Elsevier		2015	Lesson 2
Sioshansi, R., and Conejo, A.J..	Optimization in Engineering: Models and Algorithms	Springer		2017	Lesson 6
Smith, D.M.	Engineering Computation with MATLAB	Second edition, Addison-Wesley		2010	Lesson 2
Tan, Q.-M.	Dimensional Analysis with Case Studies in Mechanics	Springer-Verlag		2011	Lesson 1
Trangenstein, J.A.	Numerical Solution of Elliptic and Parabolic Partial Differential Equations	Cambridge University Press		2013	Lesson 5
Tveito, A., Langtangen, H.P., Nielsen, B.F., and Cai, X.	Elements of Scientific Computing	Springer-Verlag		2010	Lessons 3, 4 and 5
Woodford, C., and Phillips, C.	Numerical Methods with Worked Examples: MATLAB	Second edition, Springer		2012	Lessons 3 and 6
Wouver, A.V., Saucez, P., and Vilas, C.	Simulation of ODE/PDE Models with MATLAB, OCTAVE and SCÍLAB: Scientific and Engineering Applications	Springer		2014	Lessons 4 and 5
Yang, X.-S.	Engineering Optimization: An Introduction with Metaheuristic Applications	John Wiley & Sons		2010	Lesson 6
Zienkiewicz, O.C., Taylor, R.L., and Zhu, J.Z.	The Finite Element Method: Its Basis and Fundamentals	Seventh edition, Elsevier		2013	Lesson 5