UNIVERSIDAD DE CASTILLA - LA MANCHA
GUÍA DOCENTE

1. General information

Course:	TANSPORT PARTIAL DIFFERENTIAL EQUATIONS IN KINETIC THEORY AND FLUID MECHANICS	**Code:**	310940
Type:	ELECTIVE	**ECTS credits:**	6
Degree:	2351 - MASTER DEGREE PROGRAMME IN PHYSICS AND MATHEMATICS-FISYMAT	**Academic year:**	2023-24
Center:		**Group(s):**	20
Year:	1	**Duration:**	First semester
Main language:	Spanish	**Second language:**	English
Use of additional languages:		**English Friendly:**	Y
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	

2. Pre-Requisites

To achieve the learning objectives of the course, previous knowledge and skills are assumed to have been acquired during undergraduate studies. In particular, it is necessary to have a solid knowledge of ordinary differential equations and familiarity with partial differential equations, as well as basic knowledge of mathematical analysis and topology.

Also, it is very convenient to be acquainted with scientific text editors (e.g., *LaTeX*, *Microsoft Word*, *Scrivener*, *LyX*, *MathCast*, *Notepad*, *Writebox*, *Writer*, *Google Docs*, *etc*) and to be familiar with the use of numerical and symbolic calculation software (*Matlab*, *Mathematica*, *Python*, *Octave*, *Julia*, *Maple*, etc).

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

In all European countries there is a clear tendency towards the creation and consolidation of interdisciplinary studies. Given the interdisciplinarity of modern science, versatile graduated students come out, who also adapt better to changing technologies and markets, so that technological transfer processes are improved. In many fields of Physics or Mathematics a series of mathematical concepts (fractals, chaos, bifurcations, attractors, solitons, complex systems, interfaces, cellular automata, pattern formation, catastrophes, critical phenomena, self-similarity, self-criticality, scale invariance, renormalization group, ...) have recently been extended today to some of the most promising scientific research lines. At present the relationship between Physics and Mathematics and other sciences is providing important perspectives and new exploration pathways for the future. The comprehension of reality through its modeling is a fascinating and motivating challenge in nearby fields such as Engineering, Biology, Medicine, Economics, Ecology or Telecommunications. One of the purposes of this course is to strengthen and provide the necessary tools that allow connecting with these lines of work, creating the teaching structures that facilitate learning by means of a problem-solving approach in these areas.

At present, it seems commonly accepted that the great challenge of physics and mathematics in the 21st century, as well as the international repertoires and calls, is the interaction with biology and medicine, which FisyMat intends to promote with a specialty or module. In some countries a term that includes part of the previous ideas begins to be generic: mathematical or physical engineering (also bioengineering). Our point of view, regardless of the denomination, is that this program from physics and mathematics is a commitment to a return to the essence of the origins of science: the knowledge of reality and the resolution of problems that is the basic idea of an integral science, without borders.

The program of this course aims to familiarize students with the modeling of complex physical systems in which a large number of particles or dynamic agents can interact through partial differential equations. Special attention will be given to problems originated in Kinetic Theory and Fluid Mechanics. Likewise, a theoretical basis of the variational formulation and analytical resolution techniques will be provided. Since PDEs appear in almost any field of Mathematics and Physics and lately it is gaining importance in other fields such as Biology, Medicine or Economics, it is a fundamental subject.

This course will also present a great interrelation with other subjects such as Dynamic Systems, Numerical Methods, Optimization and Biomathematics, to name just a few examples.

4. Degree competences achieved in this course

Course competences

Code	Description
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
CB10	Have the learning skills which allow to continue studying in a self-directed or autonomous way
CE01	Solve physical and mathematical problems, planning their solutions based on the available tools and time and resource constraints
CE05	Know how to obtain and interpret physical and/or mathematical data that can be applied in other branches of knowledge
CE07	Ability to understand and apply advanced knowledge of mathematics and numerical or computational methods to problems of biology, physics and astrophysics, as well as to build and develop mathematical models in science, biology and engineering
CG03	Present publicly the research results or technical reports, to communicate the conclusions to a specialized court, interested persons or organizations, and discuss with their members any aspect related to them
CG05	Gain the ability to develop a scientific research work independently and in its entirety. Be able to search and assimilate scientific literature, formulate hypotheses, raise and develop problems and draw conclusions from the obtained results

CT03	Develop critical reasoning and the ability to criticize and self-criticize
CT05	Autonomous learning and responsibility (analysis, synthesis, initiative and teamwork)

5. Objectives or Learning Outcomes

Course learning outcomes

Description

The previous point implies that the student will be able to handle easily specialized literature in EDPs

Carry out a critical analysis of a scientific article that addresses topics related to the course

Deepen aspects of modeling through the study of different interaction nuclei that represent shock, coagulation, fragmentation or dispersion phenomena

Learn non-linear analysis techniques to study the qualitative behavior of problem solutions from Kinetic Theory. This will allow to identify the qualitative and analytical differences between dispersion and diffusion models.

6. Units / Contents

Unit 1: Introduction to PDEs in Science and Engineering

Unit 2: Analytic Methods for Solving PDEs of First Order

Unit 3: Variational Formulation

Unit 4: Models of Linear Transport PDEs in Kinetic Theory and Fluid Mechanics

Unit 5: Analytic Methods for Solving Linear Transport PDEs

Unit 6: Models of Nonlinear Transport PDEs

7. Activities, Units/Modules and Methodology

Training Activity	Methodology	Related Competences (only degrees before RD 822/2021)	ECTS	Hours	As	Com	Description
Class Attendance (theory) [ON-SITE]	Lectures	CG05 CT03	1.2	30	N	-	
Class Attendance (practical) [ON-SITE]	Problem solving and exercises	CG05 CT03	0.6	15	N	-	
Final test [ON-SITE]	Assessment tests	CB07 CB10 CE01	0.2	5	Y	Y	
Writing of reports or projects [OFF-SITE]	Project/Problem Based Learning (PBL)	CE05 CE07 CG03 CG05	2	50	Y	Y	
Study and Exam Preparation [OFF-SITE]	Self-study	CG05 CT03 CT05	2	50	N	-	
		Total:	**6**	**150**			
		Total credits of in-class work: 2					**Total class time hours: 50**
		Total credits of out of class work: 4					**Total hours of out of class work: 100**

As: Assessable training activity

Com: Training activity of compulsory overcoming (It will be essential to overcome both continuous and non-continuous assessment).

8. Evaluation criteria and Grading System

Evaluation System	Continuous assessment	Non-continuous evaluation*	Description
Theoretical papers assessment	100.00%	0.00%	Problem handouts
Final test	0.00%	100.00%	Final Test.
Total:	**100.00%**	**100.00%**	

According to art. 4 of the UCLM Student Evaluation Regulations, it must be provided to students who cannot regularly attend face-to-face training activities the passing of the subject, having the right (art. 12.2) to be globally graded, in 2 annual calls per subject , an ordinary and an extraordinary one (evaluating 100% of the competences).

Evaluation criteria for the final exam:

Continuous assessment:

The final grade of the ordinary call will correspond to the weighted average of all the problem handouts proposed after completing the presentation of each lesson. The course will be passed when the obtained grade is greater than or equal to 5.0. In case of not reaching that grade, the student will have to do a global exam of the Course.

Non-continuous evaluation:

Unless stated otherwise, continuous evaluation criteria will be applied to all students. The student should inform in advance, before the end of the class period, that they wish to follow a non-continuous assessment.

The final grade of the ordinary call will correspond to the weighted average of all the problems handouts proposed and submitted by the student before the end of January. The course will be passed when the obtained grade is greater than or equal to 5.0. In case of not reaching that grade, the student will have to do a global exam of the Course.

Specifications for the resit/retake exam:

In case of not having obtained a grade equal to or higher than 5.0 in the ordinary call, the student will have to do a global exam of the Course in the extraordinary call.

9. Assignments, course calendar and important dates

Not related to the syllabus/contents	
Hours	**hours**
Unit 1 (de 6): Introduction to PDEs in Science and Engineering	

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	6
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	3
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	9
Study and Exam Preparation [AUTÓNOMA][Self-study]	9
Unit 2 (de 6): Analytic Methods for Solving PDEs of First Order	
Activities	**Hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	2
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	1
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	5
Study and Exam Preparation [AUTÓNOMA][Self-study]	5
Unit 3 (de 6): Variational Formulation	
Activities	**Hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	10
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	5
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	12
Study and Exam Preparation [AUTÓNOMA][Self-study]	12
Unit 4 (de 6): Models of Linear Transport PDEs in Kinetic Theory and Fluid Mechanics	
Activities	**Hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	5
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	10
Study and Exam Preparation [AUTÓNOMA][Self-study]	10
Unit 5 (de 6): Analytic Methods for Solving Linear Transport PDEs	
Activities	**Hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	5
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	3
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	9
Study and Exam Preparation [AUTÓNOMA][Self-study]	9
Unit 6 (de 6): Models of Nonlinear Transport PDEs	
Activities	**Hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	2
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	1
Final test [PRESENCIAL][Assessment tests]	5
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	5
Study and Exam Preparation [AUTÓNOMA][Self-study]	5
Global activity	
Activities	**hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	30
Final test [PRESENCIAL][Assessment tests]	5
Writing of reports or projects [AUTÓNOMA][Project/Problem Based Learning (PBL)]	50
Study and Exam Preparation [AUTÓNOMA][Self-study]	50
Class Attendance (practical) [PRESENCIAL][Problem solving and exercises]	15
Total horas:	150

10. Bibliography and Sources

Author(s)	Title/Link	Publishing house	Citv	ISBN	Year	Description
Venerus D.C., Öttinger H.C.	A Modern Course in Transport Phenomena	Cambridge University Press		978-1-107-12920-7	2018	
Bird R.B., Stewart W.E., Lightfoot, E.N., Klingenberg, D.J.	Introductory Transport Phenomena	John Wiley & Sons		978-1-118-77552-3	2015	
Brenn G.	Analytical Solutions for Transport Processes: Fluid Mechanics, Heat and Mass Transfer	Springer		978-3-662-51421-4	2017	
Brezis H.	Functional Analysis, Sobolev Spaces and Partial Differential Equations	Springer		978-0-387-70913-0	2011	
Debnath L.	Nonlinear Partial Differential Equations for Scientists and Engineers	Birkhäuser		978-0-8176-8264-4	2012	
Evans L.C.	Partial Differential Equations	American Mathematical Society		978-0-8218-9474-3	2010	
Haberman R.	Applied Partial Differential Equations with Fourier Series and Boundary Value Problems	Pearson Education		978-0-321-79705-6	2013	
Rieutord M.	Fluid Dynamics: An Introduction	Springer		978-3-319-09351-2	2015	
Kasman A.	Glimpses of Soliton Theory: The Algebra and Geometry of Nonlinear PDEs	American Mathematical Society		978-0-8218-5245-3	2010	
Logan J.D.	An Introduction to Nonlinear Partial	John Wiley &		978-0-470-22595-0	2008	

	Differential Equations	Sons		
Logan J.D.	Applied Partial Differential Equations	Springer	978-3-319-12492-6	2015
Myint-U T., Debnath L.	Linear Partial Differential Equations for Scientists and Engineers	Birkhäuser	987-0-8176-4393-5	2007
Perthame B.	Transport Equations in Biology	Birkhäuser Verlag	978-3-7643-7841-7	2007
Salsa S.	Partial Differential Equations in Action: From Modelling to Theory	Springer-Verlag	978-3-319-15092-5	2015
Salsa S., Vegni F.M.G., Zaretti A., Zunino P.	A Primer on PDEs: Models, Methods, Simulations	Springer-Verlag	978-88-470-2861-6	2013
Soto R.	Kinetic Theory and Transport Phenomena	Oxford University Press	978-0-19-871606-8	2016
Ruocco G.	Introduction to Transport Phenomena Modeling: A Multiphysics, General Equation-Based Approach	Springer	978-3-319-66822-2	2018
Bagchi B.K.	Partial Differential Equations for Mathematical Physicists	CRC Press, Taylor & Francis Group	978-0-367-22702-9	2020
Henner V., Belozerova T., Nepomnyashchy A.	Partial Differential Equations: Analytical Methods and Applications	CRC Press, Taylor & Francis Group	978-1-138-33983-5	2020
Ramachandran P.A.	Advanced Transport Phenomena: Analysis, Modeling and Computations	Cambridge University Press	978-0-521-76261-8	2014