Course guides
200171 - MMF - Mathematical Models in Physics

Unit in charge:        School of Mathematics and Statistics
Teaching unit:        748 - FIS - Department of Physics.
Degree:               BACHELOR'S DEGREE IN MATHEMATICS (Syllabus 2009). (Compulsory subject).
Academic year: 2021   ECTS Credits: 7.5   Languages: Catalan, Spanish

LECTURER
Coordinating lecturer: CARLES BATLLE ARNAU
Others:                Segon quadrimestre:
                       CARLES BATLLE ARNAU - M-A
                       NARCISO ROMAN ROY - M-A

PRIOR SKILLS
The course "Mathematical Models of Physics" is the second general physical content and the first block of matter "modeling" Math Grade FME. This subject is based on the knowledge of the subject of Physics in Q4 and expands its own theoretical formulations of classical mathematical physics using mathematical tools, mainly from multivariable calculus, that the student knows at this point. The course should also provide a base to discuss real systems such as in "Mathematical models of technology" and in different subjects as "Dynamical systems and analysis" and "Numerical methods and engineering."

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. CE-1. Propose, analyze, validate and interpret simple models of real situations, using the mathematical tools most appropriate to the goals to be achieved.
2. CE-2. Solve problems in Mathematics, through basic calculation skills, taking in account tools availability and the constraints of time and resources.

Generical:
5. CB-1. Demonstrate knowledge and understanding in Mathematics that is founded upon and extends that typically associated with Bachelor's level, and that provides a basis for originality in developing and applying ideas, often within a research context.
6. CB-2. Know how to apply their mathematical knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader or multidisciplinary contexts related to Mathematics.
7. CB-3. Have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements.
8. CB-4. Have the ability to communicate their conclusions, and the knowledge and rationale underpinning these to specialist and non-specialist audiences clearly and unambiguously.
9. CG-1. Show knowledge and proficiency in the use of mathematical language.
10. CG-2. Construct rigorous proofs of some classical theorems in a variety of fields of Mathematics.
11. CG-3. Have the ability to define new mathematical objects in terms of others already know and ability to use these objects in different contexts.
12. CG-4. Translate into mathematical terms problems stated in non-mathematical language, and take advantage of this translation to solve them.
13. CG-6 Detect deficiencies in their own knowledge and pass them through critical reflection and choice of the best action to extend this knowledge.
Transversal:
14. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
15. SUSTAINABILITY AND SOCIAL COMMITMENT. Being aware of and understanding the complexity of social and economic phenomena that characterize the welfare society. Having the ability to relate welfare to globalization and sustainability. Being able to make a balanced use of techniques, technology, the economy and sustainability.
17. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
18. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.

TEACHING METHODOLOGY

The course is designed for a total of 65 teaching hours (13 weeks) in 39 hours of theory sessions and 26 hours of practical sessions (problems). Both in the theoretical and, above all, in the practice sessions, we try to involve the students in their development, inviting them to solve the problems proposed and even to develop a theoretical section.

In the sessions of problems, besides the exercises to be discussed in class, other ones will be delivered to the students. Some of them will be required, and the others could be delivered voluntarily. These exercises would be discussed in the tutorial hours or, exceptionally, in class.

Another objective is to habituate the students to use English bibliography. Catalan and spanish will be both used in the courses.

LEARNING OBJECTIVES OF THE SUBJECT

The main goal of the course is the familiarization with the core ideas of three fields of classical physics and of quantum mechanics, and their mathematical formulations. The student will acquire the conceptual tools that will allow him to progress in these fields in an autonomous way, and to interact with physicists and engineers.

The detailed learning objectives are:
• To understand the Lagrangian and Hamiltonian formulations of mechanics.
• To use the calculus of variations in order to state the variational principles of mechanics, and their connection with symmetries and conservation laws via Noether’s theorem.
• To apply the Lagrangian and Hamiltonian frameworks to discuss complex mechanical problems.
• To describe the Minkowskian formulation of special relativity and the transformations of Lorentz and Poincaré.
• To understand the Lorentz covariance of Maxwell equations.
• To apply the equations of special relativity to solve simple kinematical problems.
• To understand the basic formulation of relativistic dynamics and their application to simple collision problems.
• To understand the several conservation laws of fluids mechanics, both in integral and differential forms.
• To describe Euler and Navier-Stokes equations, and their dominions of validity.
• To understand the historical evolution of quantum mechanics.
• To describe the basic principles of quantum mechanics, and the main differences with respect to classical mechanics.
• To solve simple problems in the framework of quantum mechanics, both with a finite and infinite number of degrees of freedom, mainly in one space dimension.

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Hours small group</td>
<td>30,0</td>
<td>16.00</td>
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<tr>
<td>Hours large group</td>
<td>45,0</td>
<td>24.00</td>
</tr>
<tr>
<td>Self study</td>
<td>112,5</td>
<td>60.00</td>
</tr>
</tbody>
</table>

Total learning time: 187.5 h
## CONTENTS

### Classic mechanics

**Description:**
Constraints. Generalized coordinates and velocities.

**Full-or-part-time:** 16h
Theory classes: 10h
Practical classes: 6h

### Special relativity

**Description:**

**Full-or-part-time:** 15h
Theory classes: 9h
Practical classes: 6h

### The equations of fluid mechanics

**Description:**
1) Euler equations: mass balance, momentum balance, transport theorem, energy balance, Bernoulli's theorem.
2) Navier-Stokes equations: stress tensor, viscosity, Newtonian fluids, Reynold's number, dissipation of energy in a viscous fluid.

**Full-or-part-time:** 10h
Theory classes: 6h
Practical classes: 4h
Quantum mechanics

Description:
1) Introduction. 100 years of evolution, from Planck to quantum computing.
Mathematical tools of quantum mechanics.
2) The formalism of quantum mechanics. States and operators. Pure and mixed states.
Schrödinger equation. Temporal evolution images.
Composed systems. measurement and correlation.

Full-or-part-time: 24h
Theory classes: 15h
Practical classes: 9h

GRADING SYSTEM
At the end of the first two parts of the course there is a first partial exam, with a 45% weight in the final qualification of the subject.
After finishing the course, students can choose to perform a second partial exam of the two remaining parts, weighting 45% of the final grade, or a final exam of the entire course, whose value would be, in this case, 90% of the final grade.
The remaining 10% will come from the correction of the problems submitted by the students during the course.
An extra exam will take place on July for students that failed during the regular semester.

BIBLIOGRAPHY

Basic:

Complementary:
- Goldstein, Herbert; Safko, Joh; Poole, Charles P. Classical mechanics. 3rd ed. San Francisco [etc.]: Addison-Wesley, cop. 2002. ISBN 0201657023.

RESOURCES

Hyperlink:
- Aaronson, S. Resource

Other resources:
1) S. Aaronson, Introduction to quantum information science, UT course (Austin), 2017. Course materials can be found here: https://www.scottaaronson.com/cs378/esource

2) Additional resources that will be available in ATENEA.