# 10024 - MMF - MATHEMATICAL MODELS OF PHYSICS

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 726 - MA II - Department of Applied Mathematics II
Academic year: 2009
Degree: DEGREE IN MATHEMATICS (Syllabus 1992). (Teaching unit Compulsory)
Credits: 7,5 Teaching languages: Catalonian

## Lecturers

Coordinator: XAMBO DESCAMPS, SEBASTIAN

Others: ROSELLO SAURI, LLORENÇ

## Teaching methodology

Theory lectures, problem-solving classes and a work assignment.

Theoretical sessions:
Lectures in which the topics on the syllabus are explained systematically and illustrated with selected examples.

Problem-solving sessions:
Classes devoted to solving problems related with the topics introduced in the theory lectures with student participation.

Practicals:
Assigned pieces of work based on subjects studied in lectures and dealt with in problem-solving sessions, to be carried out either individually or in small groups. Summaries of
these assignments should be presented orally and written up to be handed in on the day of the finale exam.

## Learning objectives of the subject

Focusing on the fields of mechanics, electromagnetism and special relativity, we analyse some of the most fruitful relations between mathematics and physics. This task aids in a fuller understanding both of mathematics and its applicability to interesting problems in the real world in which the knowledge acquired on the course play an important role.
* To understand the fundamental role played by mathematical modelling in the resolution of physical problems and the formulation of theories.
* The assimilation and use of the notion of a mechanical system and its theoretical and practical treatment employing the methods of Lagrange and Hamilton.
* The assimilation and use of the concept of field in physics, especially in the case of electromagentism.
* To understand the physical content of Maxwell equations and their consequencies.
* To understand the influence that the key systems have on the description of physical phenomena, and the contribution of the special relativity theory to the resolution of this arbitrariness both as regards mechanics and electromagentism.
* To encourage students in the preparation and the oral and written presentation of an assigned piece of work.

Skills to be acquired:
* To understand the Lagrangian formalism, its necessity, its advantages regarding the Newtonian formulation and how to use it for solving problems in mechanics.
* To understand the structural aspects of mechanics such as Hamilton equations, the relation between symmetries and conserved quantities (the Noether theorem and its applications) and the analysis of small oscillations (fundamental

frequencies and modes).
* To learn the fundamental elements for describing the motion of a rigid solid, the equations describing its dynamic and the most basic examples.
* To learn how to calculate both directly and using the Gauss law and the Ampère law the electric field of simple charge distributions and the magnetic field of simple current configurations.
* To understand the phenomenon of electromagnetic induction and its mathematical formulation, the notion of displacment current, its role in the formulation of the Maxwell-Ampère law and in the unification of electromagnetism and optics.
* To learn the formulation of electrodynamics in terms of vector and scalar potentials.
* To understand the necessity of restricted relativity, its relation with classical mechanics and electromagnetism, the Lorentz transformations and their most important consequencies.
* To understand the notion of quadrivector and the relativist reformulation of classical mechanics.
* To understand the relativist nature of electromagnetic field separation in an electric and magnetic field, as well as the basic consequencies of this effect.

## Content

### Classical mechanics.

Description:
Configuration space and state space. Lagrangian and Hamiltonian formulation of Newton¿s mechanics. Laws of conservation. The Noether theorem. Conservative systems with a degree of freedom. Rigid solid.

### Electromagnetic fields.

Description:
Charges, currents and the continuity equation of a charge. Electrostatic fields. Potential theory. Magnetostatic fields. Magnetic materials. Electromagnetic induction. Maxwell equations. Electromagnetic waves in the void. The energy of an electromagnetic field. Vector potential and scalar potential. Electric and magnetic phenomena in material media.

### Restricted relativity.

Description:
History of the luminiferous ether. The Lorentz-Poincaré group. Time lapse and the Fitzgerald contraction. Relativist dynamics. Relativist formulation of the electromagnetic field. Relativist optics.

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## Qualification system

Theory: two exams, one halfway through the course and the other at the end, each one based on twelve topics.
Course problems: two problem-solving sessions with points awarded towards the final result; the first concerning a problem in mechanics and the second a problem in electromagnetism.
Final exam problems: a problem on mechanics, one on electromagnetism and one on special relativity.
Assignment: the written summary, the oral presentation and the final written report will all be taken into account.
The final course result is calculated as follows:
0.889 * (0.3 * Theory + 0.2 * Course problems + 0.4 * Final exam problems) + 0.2 * Assignment.

## Prior skills

* Calculus 3
* ODEs
* Differential Geometry

## Bibliography

Basic:

Goldstein, H. Classical mechanics. Addison-Wesley, 2003.

Chow, T.L.. Classical mechanics. John Wiley, 1995.

Lorrain, P.; Corson, D.R.; Lorrain, F.. Fundamentals of electromagnetic phenomena. Freeman and Co., 2000.

Cook, D.M.. The theory of the electromagnetic field. Dover, 2002.

Rindler, W.. Relativity: special, general and cosmological. Oxford University Press, 2001.

Complementary:

Jackson, J.D.. Classical electrodynamics. John Wiley, 1999.

Girbau, J.. Geometria diferencial i relativitat. Edicions UAb, 1993.

Rañada, A.. Dinámica clásica. Alianza Universidad, 1990.

Misner, G.W.; Thorne, K.S.; Wheeler, J.A.. Gravitation. Freeman and Co., 1973.

Griffiths, D.J.. Introduction to electrodynamics. Prentice and Hall, 1999.