1. OVERVIEW

Subject area	Electromagnetism II
Degree	Bachelor's Degree in Physics
School/Faculty	School of Architecture, Engineering and Design
Year	Second
ECTS	6
Type	Core
Language(s)	Spanish
Delivery mode	On campus
Semester	Second

2. INTRODUCTION

Until not that long ago, the connection between electricity and magnetism remained undiscovered. As such, they used to be thought of as two unrelated phenomena. However, at the start of the 19th century, Ørsted discovered that an electric current could interact with the needle on a compass and, therefore, that electricity could produce magnetism.

A few years later, Faraday discovered that a moving magnet could generate electricity, therefore establishing a reciprocal relationship. Drawing on the findings of previous experiments, Maxwell was then able to summarise the theory of electromagnetism in four equations. These four equations, in combination with the Lorentz force, contain everything we know about electromagnetism.

The subject area "Electromagnetism" is essential for any physics or engineering student as it forms not only a basis for other fields of study, such as optics, but also the very foundations of our civilisation.

The subject area is divided into two parts: one in the first semester and one in the second semester of the second year of the Bachelor's Degree in Physics. The aim of the first part, Electromagnetism I, is to consolidate the fundamental knowledge acquired about the theory of electromagnetism in the subject area Fundamentals of Physics II. During the course, mathematical formalism will be used to formulate Maxwell's equations in their differential and integral forms. The course begins with the study of electrostatics, both in a vacuum and in matter (metal and dielectric materials). This is followed by the study of magnetostatics, also both in a vacuum and in matter (diamagnetic, paramagnetic and ferromagnetic materials). The course ends with the study of electromagnetic induction and the formulation of Maxwell's equations of electromagnetism in their classical form.
By the end of the subject area, students will have understood what Maxwell's equations mean and they will have developed the skills needed to solve electromagnetism problems using vector analysis, partial differential equations, boundary value problems, etc.

In the subject area Electromagnetism II, we'll start with some general previous concepts about waves and then, based on Maxwell's equations, we'll prove the existence of the electromagnetic waves that surround our lives; from the light that illuminates us to the waves in free space that make our mobile phones work

and the waves guided by optical fibre that brings us high-speed communication. As such, after an initial recap, the subject area studies electromagnetic waves in a vacuum and in other media, in free space and in waveguides. In addition, we'll study the transmission lines that transport electrical signals (tension), which are also waves. We'll analyse the phenomenon of antenna radiation and finish with the connection between electromagnetism and relativity.

3. SKILLS AND LEARNING OUTCOMES

Basic skills and general skills (CB and CG, respectively, by their acronym in Spanish):

- **CB1.** Students have shown their knowledge and understanding of a study area originating from general secondary school education, and are usually at the level where, with the support of more advanced textbooks, they may also demonstrate awareness of the latest developments in their field of study.

- **CB4.** Students can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.

- **CG1.** To understand key concepts, methods and findings in the different branches of physics while gaining a historical perspective of their development.

- **CG5.** To understand diverse phenomena that, despite being physically different, share certain similarities, allowing known solutions to be applied to new problems.

Transversal skills (CT, by the acronym in Spanish):

- **CT4**. Written communication/Oral communication: Ability to communicate and gather information, ideas, opinions and viewpoints in order to understand and be able to act upon them, whether they are through spoken word and gestures, or through written word and/or visual aids.
- **CT5**. Problem solving: Be able to critically evaluate information, separate complex situations into their constituent parts, recognise patterns, and consider alternatives, different approaches and perspectives in order to find optimal solutions and negotiate efficiently.

Specific skills (CE, by the acronym in Spanish):

- **CE02.** To describe and analyse physical systems, identifying fundamental concepts and principles to make the approximations needed to build a simplified model.

- **CE03.** To understand the inherent limitations of classical physics that led to the emergence of the general and special theories of relativity and quantum mechanics, resulting in solutions to new physics problems.

- **CE04.** To understand the laws and principles of physics, to identify their logical and mathematical structure, their experimental basis and the phenomena described through them.
- **CE05.** To understand and know how to use the mathematical and numerical methods used in physics and in handling experimental data.

Learning outcomes (RA, by the acronym in Spanish):

- **RA1:** To analyse the propagation and radiation of electromagnetic waves.
- **RA2:** To identify mechanisms for the emission of electromagnetic radiation.
- **RA3:** To deduce the link between electromagnetism and the theory of relativity.

The following table shows how the skills developed in the course match up with the intended learning outcomes:

Skills	Learning outcomes
CB1, CB4, CG5, CT4, CT5, CE02, CE04, CE05	**RA1:** To analyse the propagation and radiation of electromagnetic waves.
CB1, CB4, CG1, CG5, CT4, CT5, CE04, CE05	**RA2:** To identify mechanisms for the emission of electromagnetic radiation.
CB1, CB4, CG1, CG5, CT4, CT5, CE03	**RA3:** To deduce the link between electromagnetism and the theory of relativity.

4. CONTENTS

This subject is organised into the following learning units (UA, by the acronym in Spanish):

- **UA1 Maxwell's equations, potentials and electromagnetic fields:** Maxwell's equations. Conservation laws. Scalar and vector potential.
- **UA2 Electromagnetic waves:** Plane waves. Waves in a vacuum. Waves in matter. Absorption and dispersion. Polarisation. Reflection and transmission.
- **UA3 Guided waves:** Types of waveguides. TE, TM and TEM modes of propagation.
- **UA4 Radiation:** Dipole radiation. Point charges.
- **UA5 Electrodynamics and relativity:** Special theory of relativity. Relativistic Mechanics. Relativistic electrodynamics.
- **UA6 Transmission lines:** Wave propagation through transmission lines with and without losses. Characteristic impedance and speed. Attenuation in lines with losses.

The distribution of this content is subject to change for logistical reasons. Students will be informed of any changes in due time and course.

5. TEACHING/LEARNING METHODS

The types of teaching/learning methods are as follows:

- **Lectures**: presentations by the professor with the necessary technological tools to maximise comprehension of the learning content.
- **Collaborative learning:** Students learn to collaborate with other people (classmates and professors) in order to find creative, comprehensive and constructive solutions to questions and problems that arise from the given case studies, using all relevant knowledge and material resources available.
- **Problem-based learning:** Students are given problems and asked to solve them, working individually or in groups.
- **Guided academic activities:** Individual and group work that is more independent, including information searches, written summaries, debates and the public defence of projects.

6. LEARNING ACTIVITIES

The types of learning activities, plus the amount of time spent on each activity, are as follows:

On campus:

Learning activity	Number of hours
Lectures	40
Oral presentations of projects and debates	6
Report writing	8
Assessment	6
Practical activities (problems, written work, projects, workshops and/or lab work)	20
Tutorials	16
Independent working	54
TOTAL	**150**

7. ASSESSMENT

The assessment systems, plus their weighting in the final grade for the subject area, are as follows:

On campus:

Assessment system	Weighting
On-campus knowledge tests (assessment system 1 or SE1, by its acronym in Spanish) Students will sit two exams with theoretical/practical questions and/or problems: one midterm exam and one final exam. The weighting of the midterm exam (**Ex_{par}** by its acronym in Spanish) is 15% and the weighting of the final exam (**Ex_{fin}** by its acronym in Spanish) is 35%.	50%
Submission of exercises (SE2) During the course, exercises are submitted that are, as a compulsory requirement, completed in groups. The members of the group will assess between them the individual performance of each member.	20%
Oral defence (SE3) Students will complete a group project on a topic of their choosing related to the content of the subject area, and they will present their project in front of the class. The members of the group will assess between them the individual performance of each member.	10%
Performance observation (SE4) Performance observation covers attendance, behaviour and participation in class and participation in the subject area's optional activities and forums. In addition, in the group activities, the members of the group will assess between them the individual performance of each member.	20%

On the Virtual Campus, once the student opens the course, he/she can see all the details of the assessment activities and the deadlines and assessment procedures for each activity.

8. BIBLIOGRAPHY

The main bibliography for the subject area is as follows:

- Griffiths, D.J.: Introduction to Electrodynamics (4th edition). Prentice Hall International (1999).
- Wangsness, R. K.: Electromagnetic Fields (2nd edition). Limusa (1979).
- William H. Hayt, Jr. Teoría Electromagnética (séptima edición) . Mc Graw Hill. 2001 • Tarazona, C. G. Introducción a la Electrodinámica. DOI:10.13140/RG.2.2.19598.20804.
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- Feynman, R.P., Leighton, R.B., y Sands, M.: Lecturas de Física, Vol. II. Electromagnetismo y Materia. Addison-Wesley Iberoamericana (1987).

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- Reitz, J. R.; Milford, F. J. y Christy, R. W.: Fundamentos de la Teoría Electromagnética (4ª edición). Addison Wesley (1996).
- Jackson, J.D., Classical Electrodynamics (3rd edition). Wiley (1998).