COURSE DATA

Data Subject	
Code	34267
Name	Classical electrodynamics
Cycle	Grade
ECTS Credits	4.5
Academic year	2023 - 2024

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	4	First term
1928 - D.D. in Physics-Mathematics	Double Degree Program Physics and Mathematics	5	First term
1929 - D.D. in Physics-Chemistry	Double Degree Program Physics and Chemistry	5	First term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	15 - Expansion of Physics	Obligatory
1928 - D.D. in Physics-Mathematics	5 - Quinto Curso (Obligatorio)	Obligatory
1929 - D.D. in Physics-Chemistry	5 - Quinto Curso (Obligatorio)	Obligatory

Coordination

Name	Department
GARRO MARTINEZ, NURIA	175 - Applied Physics and Electromagnetism
GIMENO MARTINEZ, BENITO	175 - Applied Physics and Electromagnetism

SUMMARY

Classical Electrodynamics studies the interaction of electromagnetic fields with moving charges and radiation of the same, representing a continuation of the third year regarding electromagnetism and matter of second year Mechanical Engineering. To take this course is also essential to have passed all the subjects of Mathematics. The content of electrodynamics is essential to study other subjects related to particle physics, astrophysics, atomic physics and quantum mechanics.

The course is 4.5 ECTS credits allocated, and teaching is provided in the first quarter of fourth grade.

The course begins with the definition of scalar and vector potentials for the case of arbitrary time variation, and changes in contrast or gauge, detailing the contrasts of Coulomb and Lorenz. The solution of differential equations of the potentials allow us to find the retarded potentials and fields of radiation (equations Jefimenko). Finely study the multipolar development of a distribution of charges and currents in the case of harmonic terms obtained electric dipole, magnetic dipole and electric quadrupole.

We will continue the study of relativistic transformations of electromagnetic fields. These transformations make it possible to explain - in particular cases - the magnetism as a relativistic phenomenon. This should be described within a covariant formulation to be consistent with the theory of special relativity. Be formulated Maxwell's equations prior definition of the electromagnetic field tensor.

Classical Electrodynamics then study the motion of charged particles within an electromagnetic field. Starting with the derivation of relativistic Lagrangian of a charge in an electromagnetic field; study some cases of motion of charges within simple configurations of electric and magnetic fields.

Finally, consider the phenomenon of electromagnetic radiation loads. Starting with obtaining the potentials of a moving charge (Liénard-Wiechert potentials) are obtained expressions of electromagnetic fields radiated by a point charge in arbitrary motion. Then study the electromagnetic radiation of a charge moving relativistically slowly, finding expressions for the Larmor formula for the two situations. Examples of implementation will address the analysis of a linear accelerator and a circular accelerator (synchrotron radiation).

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

To take this course is desirable that students had previously studied the following subjects: General Physics, Mechanics, Electromagnetism, Mathematics, Mathematical Methods.

OUTCOMES

1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.

- Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .
- Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).
- Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.
- Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.
- Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.
- Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.
- Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.
- Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.
- Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.
- Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.
- Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.
- Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

LEARNING OUTCOMES

• Manage basic conceptual schemes arising in Electrodynamics, understood as a subject where Mechanics and Electromagnetism materials are combined in a relativistic environment. Study of both Coulomb and Lorenz gauges, retarded potentials, radiation fields, multipole expansion (in frequency domain), covariant formulation, electromagnetic field tensor motion of a particle in an electromagnetic field, Liénard-Wiechert potentials, Larmor formula, and synchrotron radiation.

• Understanding the phenomenon of electromagnetic radiation from two different points of view: the radiation of continuous distributions of charges and currents (antennas), and radiation of accelerated particles. Understand that both views correspond to the same physical reality.

• Studying magnetism as a relativistic phenomenon. Understand the transformations of electromagnetic fields in the context of special relativity and master the use of the covariant formulation.

• Study the motion of a charged particle within an electromagnetic field with Lagrangian relativistic formulation; analysis of practical applications.

• Study of the electromagnetic radiation of an accelerated charge. Solve particular cases of practical interest for the world of accelerator physics, astrophysics, etc.

DESCRIPTION OF CONTENTS

1. Electromagnetic radiation of extended sources

This first issue of course intended as a transition between the subject matter of the third year Electromagnetism and Classical Electrodynamics, and could be located in the third year. We begin by formulating Maxwell's equations in a region with charges and currents, and generalize the definition of the electric and magnetic scalar potential to the case of arbitrary time variation. Then we study the gauge transformations, detailing the Coulomb and Lorenz contrasts with all its properties. Next, we solve the differential wave equation with sources under the Lorenz contrast, finding the retarded potentials (in the scenario of a Green´s function formulation). Their derivation allow us to find electric and magnetic radiation fields (equations of Jefimenko). Finally we will study the development of a multipolar distribution of charges and currents in the harmonic case, obtaining the electric dipole terms, magnetic dipole and electric quadrupole.

2. Covariant formulation of the electromagnetic field

This second chapter is concerned with the study of relativistic transformations applied to electromagnetic fields. After recalling the Lorentz transformations (and relativistic kinematics and dynamics) in the framework of a covariant formulation, we introduce the electromagnetic field tensor which can get naturally be transformed in the context of the covariant formulation of electromagnetic fields. Maxwell's equations in covariant notation will be developed, along with scalar and vector potentials, explaining all properties.

3. Dynamics of relativistic charged particles in electromagnetic fields

In the third chapters electrodynamics study the relativistic motion of charged particles within an electromagnetic field. Beginning with the deduction of the Lagrangian and Hamiltonian of a relativistic charge in an electromagnetic field, we study some particular cases related with particle accelerators.

4. Electromagnetic radiation emited by charged particles

In the last chapter the phenomenon of electromagnetic radiation from charged particles is studied. Beginning with derivation of the scalar and vector potential (Liénard-Wiechert potentials), the expressions of electromagnetic fields radiated by a point charge in arbitrary motion is obtained. Then we study the electromagnetic power radiated by a charge that moves slowly and relativistically, finding the expressions of the Larmor and Lienard formulas valid for both situations, respectivelly. Application examples as linear and circular accelerators will be studied, remarking the concept of synchrotron radiation. Finally, an introduction of the Abraham-Lorentz problem will be developed.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Development of individual work	14,50	0
Preparation of evaluation activities	8,00	0
Preparing lectures	25,00	0
Resolution of case studies	20,00	0
TOTAL	**112,50**	

TEACHING METHODOLOGY

The course will consist of two types of classes with different methodology:

(a) Lectures (2 hours/week): In these classes the basic theoretical contents of the course will be taught as well as practical examples and issues that best illustrate. To increase the ratio presentation /assimilation we can use graphical tools content presentation through PowerPoint slides, including graphs, drawings, videos and animations, combined with discussions/presentations on blackboard.

(b) Practices blackboard classes (1 hour/week): In these classes the kinds of problems will be given and discussed. In fact, students will try to solve the proposed problems in the blackboard.

EVALUATION

The assessment system consists of two parts:

1. Written examination, compulsory for every student, which shall include theoretical and conceptual questions and practical exercises. Students will be allowed to take a four page summary with the most important formulae (with no demonstrations) that will be collected by the lecturer at the end of the examen. They can bring mathematical tables, too.
2. Continuous assessment, optional: consisting in 3 or 4 problems proposed by the lecturer and presented by students along the teaching period.

Continuous assessment will have a final 30% weight in the overall mark whenever the exam rate is above 4 (out of 10).

REFERENCES

Basic

- «Classical Electrodynamics», J. D. Jackson, 3rd ed., John Wiley & Sons, Inc., 1998.
- «The Classical Theory of Fields», L. D. Landau and E. M. Lifshitz, 4th rev. ed., Elsevier, 2005.
- «Introduction to Electrodynamics», D. J. Griffiths, Ed. Pearson, 3rd ed., 2008.

Additional

- «Problemas de Electrodinámica Clásica», J. I. Íñiguez de la Torre, A. García Flores, J. M. Muñoz Muñoz, C. de Francisco Garrido, Ed. Universidad de Salamanca, 2002.
- «Problemes d'Electrodinàmia Clàssica», E. Bagan, Universitat Autònoma de Barcelona, 1998
- «Classical Electromagnetic Theory», J. Vanderlinde, John Wiley & Sons, Inc., 1993.
- «Electrodynamics of continuous media», L. D. Landau and E. M. Lifshitz, 2nd ed., Elsevier, 1999.
- «Interacción electromagnética. Teoría clásica», J. Costa Quintana, F. López Aguilar, Ed. Reverté, 2007.