

Electrodynamics and Synchrotron Radiation

Code: 100173
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	1

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

Contact

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Use of Languages

Principal working language: spanish (spa)
Some groups entirely in English: No
Some groups entirely in Catalan: No
Some groups entirely in Spanish: Yes

Teachers

Fernando López Aguilar

Prerequisites

None, but it is recommended to have done previously all the Electromagnetism and Mathematics courses.

Objectives and Contextualisation

There are two parts. In first part the most important features of the lagrangian and hamiltonian formulation of Classical Electrodynamics are presented. Maxwell equations are reobtained from first Principles (Relativity Principle, Minimum Action Principles). Also are studied conservation laws, gauge invariance and charge motion equations in electromagnetic field.

Second part is about radiation by relativistic particles. We start by introducing the concept of radiation. Then the radiation of relativistic charges is studied in depth including Bremsstrahlung, Čerenkov radiation, and in particular the study concentrates on linear accelerators and synchrotrons. We explain the spectrum and other features of synchrotron radiation.

The goal of first part is to provide the student with an unified and structured vision of Classical Electrodynamics as well as allowing him/her to understand in more depth advanced subjects as Quantum Theory of Radiation. The goal of second part is to give the student a generalized although relatively deep vision of theoretical questions and some more applied aspects of relativistic particles radiation : linear accelerators, synchrotron light sources and possibilities of experimental applications.

Competences

- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics

- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Develop the capacity for analysis and synthesis that allows the acquisition of knowledge and skills in different fields of physics, and apply to these fields the skills inherent within the degree of physics, contributing innovative and competitive proposals.
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Know the fundamentals of the main areas of physics and understand them
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Calculate Lagrangean-conserved quantities with relativistic scalar and vector fields.
2. Calculate the power radiated by accelerated relativistic particles.
3. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
4. Correctly use linear and tensor algebra in non-Euclidean spaces.
5. Describe field effects in load movement.
6. Describe how Maxwell's equations are obtained from first principles such as relativity and the principle of least action.
7. Describe the importance of gauge invariance in electrodynamics.
8. Describe the production of radiation through relativistic particles.
9. Distinguish between the assumptions implicit in a given problem and the consequences of eliminating these and, therefore, learning to generalize solutions.
10. Handle and solve partial differential equations.
11. Identify situations in which a change or improvement is needed.
12. Illustrate, in other scientific fields, the applicability of the methodology developed.
13. Obtain the equations of motion and evolution for interacting relativistic particles.
14. Pose and solve the equation of motion for a load in certain simple electromagnetic fields.
15. Recognise the importance of gauge invariance in formulating the standard model of fundamental interactions.
16. Recognise the theoretical foundations underpinning the operation of particle accelerators and radiation production.
17. Recognise the theoretical foundations underpinning the quantum theory of radiation.
18. Use approximate methods to decouple the evolution of complex systems into simpler parts.
19. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
20. Use group theory in describing symmetries.
21. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
22. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Content

Special relativity (covariant formulation). Lagrangian and Hamiltonian formulation of Classical Electrodynamics. Interaction Lagrangian, Charges in electromagnetic fields. Gauge invariance. Free field lagrangian. Maxwell Equations in covariant and vectorial forms. Energy-Momentum Tensor. Symmetries and Conservation Laws. Poynting vector.

Liénart-Wiechert Potentials. General Aspects of Radiation by relativistic particles. Larmor Formula and its relativistic generalization. Bremsstrahlung. Cerenkov Radiation. Linear Accelerators. Synchrotron Radiation. General characteristics of synchrotron radiation. Angular distribution. Synchrotron radiation spectrum. Radiation polarisation. Spectral integrated distribution.

Methodology

Theory and problem classes. Two problem deliveries included in qualification in case of improvement.

The teaching is expected to be fully presential in academic year 2021-2022 for all optative 4th year courses, according to Facultat de Ciències and the Coordinació del Grau de Física.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Theory and Problem Classes	49	1.96	2, 1, 3, 5, 6, 8, 7, 9, 12, 10, 13, 14, 19, 16, 17, 15, 21, 4, 20, 18
Type: Autonomous			
Individual Work	92	3.68	2, 1, 3, 5, 6, 8, 7, 9, 12, 10, 13, 14, 16, 17, 15, 4, 20, 18

Assessment

Two examinations (with part of theory and part of problems) and two exercises deliveries. Each examination counts up to 50% of final qualification (40% if resolution of delivered exercises is adequate). Mean value will be made if qualification of each examination plus corresponding delivery is at least 3.5 (maximum 10). Final examination allows recovery of non successful examinations. Exercises deliveries are not taken into account in this final examination.

Participation in final examination requires previous participation in both partials. No minimum qualification in partials is needed to participate in the final examination.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Final examination	100%	3	0.12	1, 3, 5, 6, 7, 9, 12, 10, 13, 14, 15, 4, 20
First partial	40-50%	3	0.12	2, 1, 3, 5, 6, 8, 7, 9, 12, 10, 13, 14, 19, 16, 17, 15, 21, 4, 20, 18
Problem Delivery	20%	0	0	2, 1, 5, 6, 8, 7, 11, 14, 17, 15, 21, 22, 18
Second partial	40-50%	3	0.12	2, 1, 3, 5, 8, 9, 12, 10, 13, 14, 19, 16, 17, 15, 21, 18

Bibliography

J.D. Jackson Classical Electrodynamics John Wiley & Sons

L.D. Landau , E. M. Lifshitz Classical Theory of Fields Pergamon Press

J. Costa Quintana, F. López Aguilar, Interacció electromagnética. Teoría Clásica. Reverté, 2007.

E. Bagan, Notes d'Electrodinàmica clàssica. UAB (Serie Materials, Num. 47) 1998.

J. Llosa, A. Molina, Relativitat Especial amb aplicacions a l'electrodinàmica clàssica. Publicacions i Edicions Universitat de Barcelona, 2004.

P.J. Duke, Synchrotron Radiation : Production and properties. OUP Oxford (Series on Synchrotron Radiation), 2008.

E. Bagan, Problemes d'Electrodinàmica clàssica, UAB (Serie Materials, Num. 51) 1998.

Software

No particular programary is used in this course.