UAB
Universitat Autònoma de Barcelona

Electrodynamics and Synchrotron Radiation

Code: 100173
ECTS Credits: 6

2024/2025

Degree	Type	Year
2500097 Physics	OT	4

Contact

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Teachers

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

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

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 équations are reobtained from first Principles (Relativity Principle, Minimum Action Principles). Also are studied conservation laws, gauge invariance and charge motion équations in electromagnétic 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, and in particular the study concentrates on linear accelerators and synchrotrons. We explain the spectrum and other features os synchrotron radiation. Breif introduction to the quantization of the electromagnetic field.

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 althoug 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. Quantization of the electromagnetic field (Gupta-Bleuler formulation).

Activities and Methodology

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

Theory and problem clases. Two problem sets will be assigned, included in the evaluation if they improve the grade.

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.

Assessment

Continous Assessment Activities

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

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 ia at least 3.5 (maximum 10). If qualification is less than 5.0 or if a qualification improvement is wished, the student can pass a final examination which is about the full semester. The qualification of the final examination (in which deliveries are not included) substitutes the previous qualification only in case of improvement.

Single Assessment: Students opting for the single assessment modality will undergo a final test comprising a theory exam (45%) and a problem-solving test (45%). In addition, they are required to submit a previously completed assignment from home (10%). These assessments will take place concurrently with the tests for the second part of the continuous assessment modality, on the same day, time, and location.

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, Interacción 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.

Language list

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	Catalan/Spanish	first semester	morning-mixed
(TE) Theory	1	Catalan/Spanish	first semester	morning-mixed