UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Electricity and Magnetism

2627-2-E3004Q007

Aims

The course aims to provide students with a comprehensive understanding of classical electromagnetism, including electrostatics, magnetostatics, electrodynamics, electromagnetic waves, and an introduction to special relativity.

By the end of the course, students will:

[Knowledge and understanding (Dublin Descriptor 1)]

- Grasp the physical meaning of electric and magnetic fields and their sources.
- Comprehend electromagnetic phenomena in vacuum and in matter.
- Understand Maxwell’s equations in integral and differential form.

[Applying knowledge and understanding (Dublin Descriptor 2)]

- Solve boundary-value problems in electrostatics and magnetostatics.
- Apply mathematical tools (vector calculus, differential equations) to solve electromagnetic problems.
- Analyze wave propagation and radiation phenomena.

[Making judgements (Dublin Descriptor 3)]

- Evaluate approximations and physical assumptions in electromagnetic models.
- Assess the validity of solutions in different physical regimes (including those relevant to special relativity).

[Communication skills (Dublin Descriptor 4)]

- Clearly present solutions to theoretical and quantitative problems.
- Use appropriate scientific language and mathematical rigor.

[Learning skills (Dublin Descriptor 5)]

- Develop autonomous problem-solving strategies.
- Build a foundation for advanced courses in theoretical physics, optics, and condensed matter.

Contents

The course covers: electrostatics, magnetostatics, electrodynamics and Maxwell's equations, electromagnetic fields in matter, electromagnetic waves and basic optics, introduction to special relativity and relativistic electrodynamics.

Detailed program

1. Mathematical Preliminaries (review): vector calculus (gradient, divergence, curl, Laplacian), integral theorems (Gauss, Stokes). [4 hours]
2. Electrostatics: Coulomb's law and electric field, Gauss's law and applications, electric potential and electrostatic energy, conductors and boundary conditions, Poisson and Laplace equations, method of images, multipole expansion. Capacitors and dielectric materials, polarization and bound charges, electric displacement field. [20 hours]
3. Magnetostatics: magnetic field and Lorentz force, electrical currents, Biot–Savart law, Ampère's law, vector potential, magnetic dipoles and magnetic energy. Magnetization and auxiliary fields, magnetic fields in matter (magnetization, susceptibility). [16 hours]
4. Electrodynamics: Faraday's law of induction, displacement current, Maxwell's equations (integral and differential forms), conservation laws (charge, energy: Poynting theorem), electromagnetic potentials and gauge transformations [12 hours]
5. Electromagnetic Waves and Optics: Wave equation in vacuum and matter, plane waves and polarization, energy and momentum of EM waves, introduction to interference and diffraction. Reflection and refraction (Fresnel coefficients), mirrors and lenses. [12 hours]
6. Introduction to Special Relativity: postulates of special relativity, Lorentz transformations, electromagnetic field transformation, covariant formulation of Maxwell's equations. [8 hours]

Prerequisites

Mathematics:

- Calculus (single and multivariable, basic vector calculus)
- Linear algebra
- Ordinary and partial differential equations (basic concepts)

Physics:

- Classical mechanics
- Basic knowledge of waves and oscillations

Skills:

- Familiarity with mathematical problem-solving
- Ability to interpret physical models

Teaching form

The course is organized into:

- In-person 2-hour frontal lectures covering part of the core theoretical content, conceptual discussions, worked examples.

- Asynchronous online lectures covering part of the core theoretical content and derivations, supplementary explanations and worked examples.

- In-person 2-hour interactive exercise sessions: problem-solving workshops, guided exercises on core topics, student participation and discussion.

This blended structure supports progressive learning, independent study skills, and continuous engagement with the material [Dublin Descriptor 5]. All lectures and sessions are in English.

Textbook and teaching resource

• D. J. Griffiths, Introduction to Electrodynamics, 4a edizione, Cambridge University Press (2017).

Semester

First semester.

Assessment method

- Mid-term test (“in itinere”) around late October/early November, covering electrostatics and magnetostatics (see Sections 1-3 of the Detailed Program). Format: multiple-choice questions, exercises and problems. Grading: score out of 30

- Final written exam. Format: multiple-choice questions, exercises and problems. The structure depends on the mid-term result: if the student passed the mid-term test, the exam covers only the remaining topics (electrodynamics, waves and optics, relativity, i.e., Sections 4-6 of the Detailed Program). Otherwise, the final exam covers the entire program. Grading: score out of 30

- Total grade from written exams: if the mid-term test is passed, the total grade is the average of mid-term and final exam results. Otherwise, the total grade is the result of the final exam only.

- An oral examination will be held after the final written exam. During the oral exam, students will be asked to discuss and clarify their written solutions and to demonstrate a solid understanding of the underlying theoretical concepts. The outcome of the oral examination may result in an adjustment of the final grade within ±3/30.

- Purpose of all exams: Evaluate foundational knowledge and problem-solving ability [Descriptors 1–2], critical thinking [Descriptor 3], communication skills [Descriptor 4].

Office hours

- Schedule (tentative): Monday and Tuesday, 10:00–12:00
- Booking: please request an appointment via e-mail at least one day in advance.

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY