UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Physics II

2627-2-E3005Q008

Aims

Classical electrodynamics: phenomenology, fundamental laws and problem solving

Contents

Sources and structure of the electromagnetic force. Phenomenology, interpretation, and formalization of electric and magnetic phenomena. Relations between fields and sources under static, quasi-static, and time-varying conditions in vacuum and material media (Maxwell's equations in vacuum and in matter). Wave propagation of electromagnetic fields and radiation fields.

Detailed program

This description describes the general layout. Topics may be covered in different order in Class 1 and 2, according to the taste and judgement of the lecturers.

Electricity and magnetism (quasi-stationary limit)

Sources and structure of the electromagnetic force. Electric charge and currents. Charge invariance and continuity equation. Static, stationary and variable phenomena.

Electrostatics: Coulomb's law and superposition principle, potential energy of a configuration of charges, electric field. Relations between field and sources: electric field flux (EC) and Gauss's law. The electric potential, potential of a charge distribution, dipoles and multipoles. Differential form of field-source relations, gradient, divergence and rotor. Notable fields.

Conductors and insulators, general problem of electrostatics, Poisson's and Laplace's equations: uniqueness theorems and boundary conditions, special solutions of Laplace's equation. Capacitance and capacitors, induction coefficients, energy stored in a capacitor.

Electric currents, definitions, conservation of charge and the continuity equation. Properties of conductors: conductivity and Ohm's law, energy dissipation (Joule's law), electromotive force, circuit elements and direct and variable current networks with resistors and capacitors.

Magnetism (stationary sources): Evidence of magnetic phenomena, Lorentz force and operational definition of magnetic field. Relations between magnetic field and stationary sources (Ampere's law and B flux). Laplace's formula and vector potential. Notable fields.

Stationary fields and reference systems. Invariance of a moving charge, electric field in different SRIs, (magnetic) field of a charge in uniform rectilinear motion, force on a moving charge, interactions between moving charges. Remarkable motions of a charge a stationary fields (and in different inertial references).

Laws of induction (quasi-stationary configurations): Magnetic induction: Faraday's observations, examples, universal law of flux, variable fields and general formulation of the law of magnetic induction (Faraday). Law of electrical induction (Ampere-Maxwell). Maxwell's equations of EMF. Quasi-stationary limit and applications of the law of magnetic induction. Mutual and self-induction, CM energy; Applications of Faraday's law and alternating current circuits.

Fields in matter (static or quasi-stationary configurations): Electric fields in dielectrics, multipoles, dipole field and potential, electric polarisation, Gauss theorem in dielectrics, notable fields and interfaces, material properties (overview). Magnetic fields in matter (quasi-stationary approximation), Ampére's law in magnetised materials, magnetic susceptibility and permittivity, dia-, para- and ferromagnetic materials (outline). Notable cases.

Electrical and magnetic phenomena with variable fields

Electromagnetic fields in vacuum: Maxwell's equations. Solutions of Maxwell's equations in vacuum. Wave equation for E and B in the absence of sources. Plane waves with generic direction, TEM waves. b) Wave equation in spherical coordinates and spherical waves; wave amplitude energy and intensity. Continuity, charge, energy and momentum equations; EM field energy and Poynting theorem, EM field momentum.

Electrodynamic potentials: quasi-stationary (retarded) and radiation fields; general method of solving with vector and scalar potentials; equations for potentials; gauge invariance; Coulomb and Lorentz gauge; wave equations for potentials; solution of wave equation for point source and generalisation to extended source; retarded potentials; variable dipole charge distribution; potential and field; quasi-stationary term and radiation term.

Accelerated charge radiation; direct calculation of E, B and ExB in the non-relativistic limit, radiated power, Larmor relation. Synchrotron radiation and relativistic correction. Radiation from localised oscillating sources, multipole terms, the electric dipole; power emitted by osciallant charge, radiation and damping, linear antenna (electric dipole), circular antenna (magnetic dipole).

Electromagnetic fields in media: Equations for time-varying fields in homogeneous and continuous media. Introduction to classical interactions of EM waves with dielectric and conducting material media.

Prerequisites

First-year physics and math courses.

Teaching form

lectures (8 credits), classes (4 credits)

Textbook and teaching resource

Class 1:

- Mazzoldi-Nigro-Voci, “Fisica Generale (vol.2)”, Edises

Class 2:

- E.M Purcell and D.J. Morin, Electricity and Magnetism, 3rd Edition, Cambridge (Amazon) -
- S. Focardi, I. Massa, A. Uguzzoni, Onde e ottica, CEA -
- Lecturer's handouts

Many topics are supplemented with additional texts (with specific references in the lectures):

- R. Feynman, The Feynman Lectures on Physics, Vol II - Available online at caltech.edu
- D.J. Griffiths, Introduction to electrodynamics, Cambridge (Rather comprehensive)
- J. Jackson, Classical Electrodynamics, Zanichelli (Advanced)

Other possible texts (in italian) include:

- Mencuccini e Silvestrini, Elettromagnetismo e Ottica, Ed. Ambrosiana
- S. Focardi, I.G. Massa, A. Uguzzoni, M. Villa, "Fisica generale - Elettromagnetismo", Zanichelli

Semester

1st semester

Assessment method

- A single two-hour written tests at the end of the course with three problems covering the following subset of topics:
    - Electrostatics in vacuum and in the presence of materila media
    - Stationary magnetic fields
    - Induction laws and quasi-stationary fields.
      Final oral examination with questions on the entire programme, conditional on passing the written tests with a mark of at least 15/30.

The written exam is common to sections T1 and T2, while the format of the oral exam may differ according to the guidelines specified by the respective instructors. Please refer to the T1 and T2 course elearning pages for a description of the evaluation criteria for the written exams and for the format of the oral exam, which may include conceptual questions and problem-solving.

The depth and extent of knowledge of course topics, the ability to use concepts to analyze novel configurations, and the clarity of exposition and use of skills learned are evaluated.

Office hours

Upon request

Sustainable Development Goals

NO POVERTY | ZERO HUNGER | GOOD HEALTH AND WELL-BEING | QUALITY EDUCATION | GENDER EQUALITY | CLEAN WATER AND SANITATION | AFFORDABLE AND CLEAN ENERGY | DECENT WORK AND ECONOMIC GROWTH | INDUSTRY, INNOVATION AND INFRASTRUCTURE | REDUCED INEQUALITIES | SUSTAINABLE CITIES AND COMMUNITIES | RESPONSIBLE CONSUMPTION AND PRODUCTION | CLIMATE ACTION | LIFE BELOW WATER | LIFE ON LAND | PEACE, JUSTICE AND STRONG INSTITUTIONS | PARTNERSHIPS FOR THE GOALS