UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Fisica II - Turno 2

2324-2-E3001Q042-T2

Aims

Classical electrodynamics and optics: phenomenology, fundamental laws and problem solving

Contents

Sources and structure of the electromagnetic force. Electrostatics and magnetism in vacuum (stationary sources), electromagnetic induction laws (variable sources) and Maxwell's equations. Electrostatics and magnetism in material media (stationary sources). Variable sources and fields, electromagnetic waves in vacuum and in media. Descriptive optics, scattering, scattering, reflection, refraction, interference and diffraction.

Detailed program

1st Semester: 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.

2nd Semester: Electrical and magnetic phenomena with variable fields; Optics

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 variable fields in homogeneous and continuous media. Interaction of EM waves with media: a) Dielectrics: Oscillator model, absorbed and radiated power, scattering and Rayleigh's law, dynamic polarisability, complex refractive index; wave propagation in a medium, normal scattering and anomalous scattering; resonant absorption; representation of a wave packet; phase velocity and group velocity; wave attenuation. (b) Conductors: Maxwell's equations in a conductor, wave equation in conductors, Helmoltz equation and complex refractive index; conductor quality as a function of frequency and conductivity; skin depth; reflection and transmission by normal incidence between dielectrics and between dielectrics and conductors.

Optics: a) Geometric optics laws; conditions of continuity of the fields and relationship with the wave number vector; Fresnel relations, reflection and tranmsmission coefficients; Brewster angle and reflection by polarization. b) Interference: conditions of interference; interference with two sources; wavefront and amplitude separators. Multiple interference and interference pattern. c) Diffraction: Huygens principle and diffraction integral; diffraction figures.

Prerequisites

First-year physics and math courses.

Teaching form

lectures (10 credits), classes (4 credits)

Textbook and teaching resource

- E.M Purcell and D.J. Morin, Electricity and Magnetism, 3rd Edition, Cambridge (Amazon) - 1st semester
- S. Focardi, I. Massa, A. Uguzzoni, Onde e ottica, CEA - 2nd semester
- 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:

- Mazzoldi-Nigro-Voci, “Fisica Generale (vol.2)”, Edises
- Mencuccini e Silvestrini, Elettromagnetismo e Ottica, Ed. Ambrosiana
- S. Focardi, I.G. Massa, A. Uguzzoni, M. Villa, "Fisica generale - Elettromagnetismo", Zanichelli

Semester

1st and 2nd semesters

Assessment method

Two two-hour written tests with three problems in each test.

- 1st test: Electrostatics and stationary magnetic fields
- 2nd test: Electrostatics in material media and variable (quasi-stationary) fields
  The two written tests can be taken in the same roll call (2+2 hours) or in two different roll calls or in itinere tests (2 hours) during the course.
  Final oral examination with questions on the entire programme, conditional on passing the written tests with a mark of at least 15/30.

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