UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Physics II - Turn 2

2223-2-E3001Q042-T2

Aims

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

Contents

Electrostatics in vacuum, Stationary electric current, Magnetostatics in vacuum, Electromagnetic induction, Electrostatics in materials, Magnetostatics in materials, Electromagnetic waves and fields, Optics.

Detailed program

1st Semester: Electricity and magnetism (quasi-stationary limit)

U1 - Coulomb's law and the principle of superposition, the potential energy of a charge configuration, the electric field and the field of a charge distribution, electric field (EF) flow, Gauss's law, examples of EF calculation for symmetric distributions, the electrical force on planar distribution, the energy associated with the EC

U2 - The electric potential, the relationship between the potential and the EF: the gradient, potential of a charge distribution, dipoles and multi-pole. The divergence of a vector, Gauss's theorem, the divergence of a vector and vector operators, differential form of Gauss's law; Laplace and Poisson equation; The rotor and the Stokes theorem, the meaning of divergence and rotor

U3 - Conductors and insulators, conductors in the EF, the general problem of the electrostatics: uniqueness theorems and boundary conditions, a way to solve the Laplace equation: the method of the image charges. Harmonic solutions (maybe). Capacitance and capacitors, induction coefficients, the energy stored in a capacitor

U4 - Electrical currents, current intensity and density, stationary currents and charge conservation, conductivity and Ohm's law, conductor properties, electrical circuits and circuit elements, energy dissipation (Joule's law), electromotive force, direct current networks and variable with resistors and capacitors

U5 - Evidence of magnetic phenomena, Lorentz force and definition of magnetic field. Relations between magnetic field and stationary sources (Ampere's law and B flux). Solutions by vector potential and Laplace's formula and/or by integration of Ampere's law. Remarkable fields (rectilinear wire, current loop and magnetic dipole, linear solenoid, toroidal solenoid, plane with surface currents, ...).

U6 - Stationary fields and reference systems. Invariance of charge in motion, electric field in different Inertial Reference Frames, (magnetic) field of a charge in uniform rectilinear motion, (interlude: field of moving and stationary charge), force on a moving charge, interactions between moving charges. Motion of a charge in stationary fields and in different inertial references

U7 - Magnetic induction: Faraday's observations, examples, the general formulation of the law of induction (Faraday-Neuman-Lenz), mutual and self-induction, the energy associated with the magnetic field. Applications. Alternating current circuits.

U8 - The displacement current, Maxwell equations of the CEM, quasi-stationary limit. Some particular solutions (plane waves) for variable fields - non-stationary - in a vacuum, energy associated with a plane wave and Pointyng vector (introductory treatment).

U9 - Electrical fields in matter, dielectrics, multipoles, field and dipole potential, electrical polarization, Gauss theorem in dielectrics, properties of materials.

U10 - Magnetic fields in matter, Ampére's law in magnetized materials, Susceptibility and magnetic permittivity, Dia-, para- and ferromagnetic materials.

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

U11 - a) Maxwell equations. Solutions of Maxwell's equations in vacuum. Wave equation for E and B in the absence of sources. Plane waves with a generic direction, TEM waves. An (ideal) source of plane waves and the explicit solution of Maxwell's equations; comparison with the wave solution. b) Wave equation in spherical coordinates and spherical waves; energy amplitude and wave intensity. Charge, energy and momentum continuity equations: the energy of the EM field and the Poynting's theorem; the momentum of the EM field.

U12 - Electrodynamic potentials: quasi-stationary (delayed) and radiation fields; general method of solution with scalar and vector potential; equations for potentials; gauge invariance; the Coulomb and Lorentz gauge; wave equations for potentials; solution of the wave equation for a point source and generalization for an extended source; the retarded potential; oscillating dipole, potential and field; quasi-stationary term and radiation term.

U13 - Radiation by an accelerated charge; direct calculation of E, B, and ExB in the non-relativistic limit, irradiated power, Larmor relation. Synchrotron radiation and relativistic correction. Radiation of localized oscillating sources, multipole terms, the electric dipole; power emitted by an oscillating charge, radiation and damping, linear antenna (electric dipole), circular antenna (magnetic dipole).

U14 - Interaction of EM waves with media: a) Dielectrics: Oscillator model, absorbed and radiated power, Rayleigh diffusion and law, dynamic polarizability, complex refractive index; propagation of waves in a medium, normal dispersion and anomalous dispersion; resonant absorption; representation of a wave packet; phase speed and group speed; wave attenuation. b) Conductors: Maxwell equations in a conductor, wave equation in conductors, Helmoltz equation and complex refractive index; quality of the conductor according to frequency and conductivity; depth of skin; Reflection and transmission by normal incidence between dielectrics and dielectrics and conductors.

U15 - Optics: a) Geometric optics laws; conditions of continuity of the fields and relationship with the wave number vector; Fresnel relations for generic incidence and polarization in the incidence plane (other polarization by

exercise); 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) - U1-10
- S. Focardi, I. Massa, A. Uguzzoni, Onde e ottica, CEA - U11-15.

Some of the topics covered in units U11-U15 are described in accordance with:

- R. Feynman, The Feynman Lectures on Physics, Vol II - Online:

Additional textbooks that may be used or suggested for further reading on selected topics include:

- D.J. Griffiths, Introduction to electrodynamics, Cambridge (Rather comprehensive)
- J. Jackson, Classical Electrodynamics, Zanichelli (Advanced)
- Mencuccini e Silvestrini, Elettromagnetismo e Ottica, Ed. Ambrosiana
- S. Focardi, I.G. Massa, A. Uguzzoni, M. Villa, "Fisica generale - Elettromagnetismo", Zanichelli
- Mazzoldi-Nigro-Voci, “Fisica Generale (vol.2)”, Edises

Semester

1st and 2nd semesters

Assessment method

Written tests structured in problems, which can be passed through two midterm tests during the course or at the end of the course.
Final oral test on the entire program, conditional on passing the written tests with a score 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