UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Laboratory of Electromagnetism

2526-3-ESM01Q016

Aims

The aim of the course is to provide theoretical and applicative knowledge of electromagnetism and optics. Through targeted laboratory experiences, the course also aims to consolidate the theoretical knowledge obtained in the Physics II course and extend it to basic concepts of circuitry. Finally, the experiences in the laboratory aim to teach experimental criteria and methodologies and data analysis.

Learning Outcomes for the course “Electromagnetism and Laboratory” expressed through the five Dublin Descriptors

1. Knowledge and understanding
   By the end of the course the student will be able to to:

- State and interrelate Kirchhoff’s laws, the constitutive relations of resistors, capacitors and inductors, and the Maxwell equations that underlie their behaviour.
- Explain the charging/discharging of capacitors, the transient response of RC and LR circuits, the oscillation of an LC circuit, and resonance and damping in LRC circuits.
- Describe the operating principles of voltmeters, ammeters, analogue/digital oscilloscopes, measurement bridges, transformers and triodes.
- Illustrate magnetic-field and induction phenomena, both static and time-varying, and the basic concepts of interferometry (Michelson interferometer).
- Summarise the fundamentals of error analysis, including type-A/B uncertainties and the least-squares method.

2. Applying knowledge and understanding
   The student will be able to:

- Solve quantitative problems on d.c. and a.c. circuits (current, voltage, impedance, power factor).
- Design simple RC and RLC filters and predict their frequency response (Bode plots).
- Apply the least-squares method to extract time constants (?), inductances and internal resistances from

experimental data.
- Set up and calibrate multimeters, oscilloscopes, function generators and RLC bridges for measurements of resistance, impedance, permeability and permittivity (??).
- Compare experimental data with models using analysis software.

3. Making judgements
   The course will develop the ability to:

- Assess the consistency between laboratory results (e.g. resistivity) and literature values, identifying the causes of discrepancies.
- Critically select instrumentation (range, sensitivity, input impedance) appropriate to each experiment.
- Identify and quantify sources of systematic error (thermal drift, instrument offsets, parasitic coupling) and propose mitigation strategies.

4. Communication skills
   At the end of the course students will be able to:

- Write technical reports for each laboratory experiment (A–M), including theoretical background, apparatus diagram, data analysis, uncertainty estimation and conclusions.
- Present orally the results of experiments (e.g. Michelson interferometer, triode characterisation) using clear graphics and multimedia support, and respond effectively to questions.
- Collaborate in teams, organising data acquisition, sharing roles (operator, analyst, presenter) and documenting the workflow in shared lab notebooks.

5. Learning skills
   The course will enable students to:

- Consult independently instrumentation manuals, component data-sheets (transformers, triodes, Hall sensors) and literature on interferometric techniques.
- Extend their experimental skills by trying additional circuit configurations (high/low-pass filters, matching networks, Wheatstone bridges) beyond classroom examples.
- Transfer measurement and analysis methods (least squares, error propagation) to related fields such as electronics, photonics and applied physics.

Contents

The course deals theoretically and practically with topics of electromagnetism presented in the Physics 2 course and complements the knowledge with the contents of analysis of direct current and alternating current circuits. Also in this case, the discussion takes place in a theoretical way with lectures and the validation of the concepts is obtained experimentally by the same students with experiences in the laboratory.

Detailed program

** The course includes the following topics covered in sequential order: **

1) Elements of error analysis with the least squares method

2) Kirkhoff laws and analysis of elementary electric circuits

3) Resistors and power supplies in series and in parallel

4) Principles of operation of voltmeters, ammeters and oscilloscopes

5) Capacitors: charge and discharge, series and parallel connection, RC circuits

6) Magnetic fields and induced currents

7) Inductors and transient behavior, LR circuits

8) Electromagnetic oscillator, LC circuit

9) Alternating current circuits: Resitive, capacitive and inductive impedance

10) LRC circuits

11) Electric transformers

12) Basics of interferometry

** Laboratory experiences are as follows: **

A) Resistivity of metals

B) Charge / discharge capacitors

C) Electrolytic cell

D) LRC

E) Triode

F) Transformers

G) Measurement of magnetic fields

H) Michelson interferometer

I) Impedance measurement

L) Resistance vs. Temperature

M) Measurement of the dielectric constant of vacuum, ?0

Prerequisites

Knowledge of mathematics and differential calculus, knowledge of electromagnetism from Physics 2, knowledge of error analysis.

Teaching form

Lectures in which the topics are dealt with in a theoretical way and the experimental methods are exposed. Practical laboratory experiences. The lessons are held in Italian language.

Textbook and teaching resource

ELEMENTS of PHYSICS, P. Mazzoldi, M. Nigro, C. Voci, EdiSES)

Error analysis book (for example INTRODUCTION TO ERROR ANALYSIS, J.R.Taylor, Zanichelli)

Notes provided by the teacher

Semester

First semester (September-November)

Assessment method

Written report on two laboratory experiences chosen by the student.

Oral exam on theoretical and practical knowledge concerning the topics of the course.

The oral exam, with a mark out of thirty, aims to verify:

1) the language property

2) knowledge of the theories addressed in the course

3) the level of understanding of the theories addressed in the course

Office hours

To be agreed with the teacher.

Sustainable Development Goals