UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Mathematical and Computational Methods for Optics

2526-1-F1702Q006

Aims

The aims of this course are: 1) to provide basic knowledge and understanding in key areas of Mathematical and Computational methods for Optics, such as Python Programming Language and basics of Fourier analysis applied to optical systems; 2) to support students in applying the acquired knowledge to optics problems, such as developing Python codes implementing mathematical and physical concepts in specific cases; 3) to help students develop critical thinking in the analysis of results, obtained from analytical, physical or modelling approaches; 4) to support students in learning how to interact with academic and research professionals in the field of simulation in optics, i.e. by means of appropriate technical and scientific language, presentation tools and related skills; 5) to develop scientific and computational competences that support students in engaging with modern avenues of (computational) optics.

Contents

- Module I – Introduction to Python Programming Language + Basic coding examples in Python
- Module II – Introduction to Fourier optics: mathematical tools, physical principles and applications
- Module III – Computer Lab of Python code applied to optics

Detailed program

Introduction to the course and its structure

Module I – Introduction to Python Programming Language:

- Interactive Programming Environments

- Type of variables, strings and expressions
- Type conversion, print and input
- Conditional statements: If, elif and else instructions
- Cycles: while and for
- Lists
- Dictionaries
- Python functions: examples
- Modules of Python Standard Library
- Data visualization

Module II – Introduction to Fourier optics: mathematical tools, physical principles and applications

- *Mathematical concepts (definition, properties, interpretation, …) of Fourier analysis:*
  o Fourier series
  o Fourier Transforms and Antitransforms
  o Convolution
  o Examples of Fourier transforms

- *Physical concepts*:
  o Review on Diffraction: Huyghens-Fresnel principle, Fresnel and paraxial approximation, Fraunhofer approximation
  o Point Spread function (PSF), Optical Transfer Function (OTF), Modulation Transfer Function (MTF)

Module III - Computer Lab of Python applied to optics

o Combination of mathematical and physical concepts for applications and specific examples in optics (involving lenses, filters, etc.)
o Implementation in Python and code development (even including import of Scientific Libraries) for specific optics applications.

Prerequisites

Appropriate mastering of the following contents: Numerical sets (natural, integer, rational, real and complex numbers). Functions of one real variable, limits, continuity, differentiability. Derivative of a function. Riemann integral and improper integral. Elementary notions of ordinary differential equations. Sequences and series. Linear algebra. Differential calculus in several variables. Line integrals. Integral calculus in several variables. Basic concepts of geometrical and physical optics.

Teaching form

- Front lessons on theoretical concepts: 26 hours in-person + 14 hours remote;
- Exercises (mathematical, physical or computational) on how to apply the theory concepts to practical optics problems: 6 hours in-person and 6 hours remote.

Lessons and exercises will be videorecorded and available on the elearning page of the course.

Textbook and teaching resource

- Slides provided by the teacher
- Python Tutorial guide from pyhton.org (or similar)
- J. D. Gaskill, “Linear Systems, Fourier Transforms, and Optics”, Editor: John Wiley & Sons (any edition)

Additional Texts

- G. J. Gbur, “Mathematical Methods for Optical Physics and Engineering”, Editor: Cambridge University Press (2011)
- J.W. Goodman, “Introduction to Fourier Optics”, Editor: W. H. freeman, Macmillan Learning (2017) (or any other editions)
- G.D.Boreman, “Modulation Transfer Function in Optical and Electro-Optical systems”, SPIE Press (any edition)

Semester

Primo semester

Assessment method

The assessment will be based on a written test (with open questions and exercises on module II) and an oral exam (which consists in i) one or more computational exercises to be solved at the moment via Python, ii) a discussion of the Python examples for optics; iii) a discussion on the written exam. The oral exam can be taken only if the written test is sufficient (grade >= 18 out of thirty). The final evaluation will be evaluated as the average of the written and oral exam, rounded to the closest integer. No intermediate exams will be carried out. Students are required to master the topics of the course and the capability to face mathematical and computational problems dealing with optics.

Office hours

by appointment arranged via email

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING **|** INDUSTRY, INNOVATION AND INFRASTRUCTURE