

# Waves propagation

 Crédits ECTS  
3 crédits

## En bref

> **Langue de cours:** Anglais

## Présentation

### Prérequis

#### Mathematics

- Single variable calculus (derivatives, integrals) [essential]
- Basic multivariable calculus (gradients, partial derivatives) [essential]
- Differential equations (how to solve basic first/second ODEs) [essential]

#### Physics

- Basic mechanics (Newton's laws) [essential]
- Basic electromagnetism [preferred]

#### Programing

- Basic programing skills of Python (or Matlab) [preferred]

### Objectifs d'apprentissage

The student after the course will:

- learn the basics of waves/wave-like phenomena;
- know how to model them correctly, both mathematically and numerically;

- understand when it is important to use them or when they can be substituted by simpler models, such as the geometric ones;
- have an overview of some biomedical applications, such as imaging techniques.

In this course, physical intuition and practical modeling are highlighted.

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## Description du programme

Waves / wave-like phenomena are present everywhere and are very important. They appear in natural phenomena and human-made devices; hence their study is essential for science and technology. Applications range from biomedical imaging (ultrasound imaging, magnetic resonance imaging, optical coherence tomography, etc.) all the way to telecommunication and detection (antennas, radar, optical fibers, etc.).

In this course a general introduction to all wave-like phenomena is given. It provides an overview of the laws and methods used for modelling the propagation of waves. Electromagnetic/optic waves are studied with more detail, however, analogies with mechanical scenarios, such as sound and shear waves, are also mentioned. Aspects covered include the theory of diffraction, refraction, reflection, as well as more advanced topics such as polarization and the statistical properties of light and other waves.

During the course we apply analytical and numerical/semi-analytical tools to tackle wave phenomena, specifically wave propagation, and to understand how they impact systems, e.g. the sensitivity and the resolution achievable in an imaging system. Alongside, geometric models will be also studied and compared. Different frameworks are described, such as the use of Fourier transforms, the ray model, and phase space descriptions.

### Teaching plan

1. Motivation of the course
  - a. Quick examples: mechanical and electromagnetic
  - b. Basic description of waves
  - c. Nuances of the wave model
2. Reminder of mathematical tools
  - a. Quick reminder of calculus and differential equations
  - b. Complex numbers
  - c. The wave equation, diffusion equation, etc.

- d. Waves: interference/superposition
- e. Fourier Series and Transforms
- f. Shift invariant linear systems
- 3. Mechanical waves
  - a. Quick reminder of mechanics and the harmonic oscillator
  - b. Vibrating cord
  - c. Continuum mechanics (deformation and elasticity)
  - d. Sound
  - e. Dispersion and other advanced notions
  - f. Application: Elastography
- 4. Electromagnetic waves I
  - a. Motivation of optics and electromagnetism
  - b. Review of Electromagnetism
  - c. Electromagnetic waves
- 5. Geometric optics
  - a. Rays, Snell's Law, Fermat's principle
  - b. Imaging optics
  - c. Paraxial optics and ABCD matrices
  - d. Application : imaging systems
- 6. Electromagnetic waves II
  - a. Motivation of wave optics
  - b. Monochromatic waves
  - c. Diffraction and propagation of light
  - d. Interfaces, media and scattering
  - e. Polarization and coherence

f. Biomedical applications: microcopy, OCT

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## Bibliographie

Wave physics (general)

- Frank S. Crawford, Waves, McGrawHill.
- Howard Georgi, The physics of waves, Prentice Hall.

Mechanical waves

- Heinrich Kuttruff, Room Acoustics, Spon Press.

Optics and electromagnetism

- Eugene Hecht, Optics, Pearson Education.
  - Joseph Goodman, Introduction to Fourier Optics, McMillan.
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## Equipe pédagogique

Luis Arturo ALEMAN-CASTANEDA (aleman-castaneda@fresnel.fr)

<b>Total des heures</b>		<b>24h</b>
CM	Cours Magistral	16h
TD	Travaux Dirigés	8h

## Infos pratiques

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### Nom responsable UE

#### Responsable pédagogique

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