1EL1500 – Physics of Waves

Instructors: Hichem Dammak
Department: DÉPARTEMENT PHYSIQUE
Language of instruction: FRANCAIS, ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35,00

Description

This course provides students with basic elements necessary to understand the physics of waves through the examples of lectromagnetism and acoustics. Many disciplines rely on those concepts : seismology, telecommunications, guided waves, imaging techniques, photonics, etc. The notions introduced in this course are basic concepts usefull to several “dominantes”.

Master Fourier analysis, understand concepts of waves and their applications in different domains :
1) spatial filtering methods, such as 4f Fourier optical assembly, for image processing
2) approximations according to the wavelength, the size of the system and the distance at which the phenomenon is observed: diffraction and radiation
3) directivity of an antenna.
4) relatioship between dielectric or optical properties and behaviour of a medium (transparent, absorbent or opaque)
5) Calculation of the reflection and transmission coefficients of a wave through an interface.

Quarter number

SG1 and SG3

Prerequisites (in terms of CS courses)

- Geometric optics (converging lens)
- Electrostatics, Magnetostatics
- Maxwell's equations in vacuum
- Electromagnetic plane wave.
- Decomposition of a periodic function in Fourier series
- Partial differential equations (Poisson's equation, d'Alembert's equation).

Syllabus

1-**Introduction** :

We present concepts and applications that students will see in the lectures through selected examples (propagation, guidance, emission, different scales ...). The place of the course shall be exposed within the new curriculum (present the courses where this course will be useful).

Mathematical preliminaries: Fourier transform, Dirac distribution.

TD1: Fourier analysis of waves, filtering.

2-**Basic principles of imaging**:

Propagation: near field, far field, evanescent waves, diffraction and self-diffraction of a wave, resolution limit.

TD2: Measurement of the Earth-Moon distance. Dimensioning the antenna of a geostationary satellite.

TD3 : Optical image processing.

3-**Wave sources** :

Electromagnetic wave sources : retarded potentials, far-field approximation, dipole approximation.

TD4 : Radiation of a wire antenna and of an antenna array.

4-**Radiation** :

Radiated field: local plane wave structure. Radiated power.

TD5 : Radiation of a mobile-phone antenna (wire).

5-**Diffusion** :

Introduction to diffusion by one or more ordered or disordered diffusers; Bragg diffraction.

TD6: Diffusion and diffraction by a 2D photonic crystal.

6-**Maxwell equations in matter**. From microscopic to macroscopic scale:

General Maxwell equations for any medium : transition to spatial averaging for the derivation of macroscopic Maxwell equations.

7-**Constitutive equations of matter**:

Effective (generalized) dielectric constant. Notions of homogeneity, linearity, isotropy, dispersion. Links between dispersion and inertia, between phase shift and dissipation.

TD7: Semi-classical model of the dielectric constant. Cases of insulating and conductive media.

8-**Free propagation in matter**:

Definition of the optical index. Meaning of the real and imaginary parts of the index and dielectric constant. Energy balance. Definition of transparent, opaque and absorbent media.

TD8 : Attenuation and energy balance of a wave in an absorbent medium

9-**Field continuity relationships** :

Snell Descartes laws. Refraction and reflection phenomena at an interface, total reflection, evanescent wave, Brewster angle.

TD9 : Anti-reflective coating for photovoltaic cells or glasses.

TD10 : Dielectric waveguide. Application to optical fiber.

TD11 : Non-linear medium. Second harmonic generation

TD12 : Brillouin diffusion : coupling between acoustic and electromagnetic waves
10-**Negative refractive refraction engineering** - Metamaterials: Propagation in a double negative media. Perfect lens, invisibility

Class components (lecture, labs, etc.)
10 lecture sessions in the Amphitheatre
12 tutorial sessions in groups of 33 students.

In the case of the **English version**, **the lecture is taught in English**, but only **one tutorial class is taught in English** (in the other two tutorial classes, the teaching is in French).

Occurrence 1.2 will be taught in English and occurrence 1.4 will be taught in French

Class components :
1 Lecture 1
2 Tutorial 1
3 Lecture 2
4 Tutorial 2
5 Lecture 3
6 Tutorial 3
7 Lecture 4 (Quizz 1)
8 Tutorial 4
9 Lecture 5
10 Tutorial 5
11 Lecture 6
12 Tutorial 6
13 Lecture 7 (Quizz 2)
14 Tutorial 7
15 Lecture 8
16 Tutorial 8
17 Lecture 9
18 Tutorial 9
19 Tutorial 10
20 Tutorial 11
21 Lecture 10 (Quizz 3)
22 Tutorial 12
23 Final Exam.

Grading
QCM with no documents (35%) Test 1 of 15 min in session 7 during Lecture 4. Test 2 of 15 min at session 13 during Lecture 7. Test 3 of 15 min at session 21 during Lecture 10. Final exam (writteen exam) of 2 hours with documents (65%).

Skill C.1 is evaluated through one of the exercises of the final written exam. If the grade for this exercise is higher than 50%, the student will have validated the C.1 skill in this course.
Skill C.2 is validated if the final average mark is higher than 10/20.

Course support, bibliography
Course and Exercises books. Corrections of exercises.

Resources
Teaching staff (instructor(s) names): Hichem Dammak, Pierre-Eymeric Janolin, Bruno Palpant, Thomas Antoni, Charles Paillard, Vincent Lescarret, Mohammed Serhir, Gaëlle Vitali-Derrien, Romain Pierrat (vacataire), Aurélie Bonnefois (vacataire)
Maximum enrollment (default 35 students): 4 TD rooms of 30 for TDs.
Software, number of licenses required: Python already installed on students' laptops
Equipment-specific classrooms (specify the department and room capacity): No

Learning outcomes covered on the course
1) **Apply** spatial filtering methods, such as 4f Fourier optical assembly, for image processing
2) **Apply** the required approximations according to the wavelength, the size of the system and the distance at which the phenomenon is observed: diffraction of a wave or radiation of an antenna
3) **Determine** the radiation area and directivity of an antenna.
4) **Describe** whether a medium is transparent, absorbent or opaque from its dielectric or optical properties.
5) **Apply** the boundary conditions for a system with one or more interfaces.
6) **Calculate** the reflection and transmission coefficients of a wave through an interface.

Description of the skills acquired at the end of the course
C1.1: Analyze the scientific aspects of the overall behavior of a small-scale system (e.g. isolated part of a complex system), including the identification of factors that influence its behavior (**diffraction, diffusion, reflection, transmission, absorption, interference**)
C1.2: Correctly use a model presented in class in its conditions of validity (model describing a phenomenon, without couplings) (**far field approximation, dipolar approximation, planar wave approximation, Fourier optics/image processing, antenna array, scattering by a periodic array, anti-reflection layer, Brillouin scattering**)
C1.3: Compare the results of a simulation with experimental measurements or approximate calculation results, taking into account measurement errors and uncertainties, or model approximations, based on the knowledge of orders of magnitude
C2.1: Deepen your knowledge of an engineering field or scientific discipline