Degree competences to which the subject contributes

At the end of the course, the students should be able to:

- identify the most appropriate approach (rays, waves, photons) for the description of the various phenomena that involve light;
- use the complex notation for describing waves and solving differential equations;
- find the solution to problems of geometric and wave optics, in particular involving the interaction of a planar wavefront with simple optical components (lenses, prisms, mirrors, gratings, etc.);
- describe the working principles behind image-forming optical systems, lasers, semiconductor optoelectronic devices, and telecommunication systems;
- write the rate equations for a laser and calculate its steady-state behavior;
- evaluate the intrinsic limitations of optical instruments and identify alternative strategies to circumvent them; discuss different tools for the analysis and processing of images;
- describe the physical mechanism behind human vision and the challenges for artificial vision.

Coordinator:

ROBERTO MACOVEZ

Teaching staff

Requirements

Participants must have passed the exams of the courses "Álgebra Lineal" and "Mecànica Fonamental", and they have to have attended the lectures of the course "Electromagnetisme".

Degree competences to which the subject contributes

Specific:

2. Capacity to solve mathematical problems that can appear in engineering. Aptitude to apply knowledge about: linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and derived partial equations; numerical methods; numerical algorithm; statistics and optimisation.


4. Understanding and dominion of basic concepts on mechanics, thermodynamics, fields and waves and electromagnetism laws and their application to solve engineering problems.

Transversal:

1. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.

Teaching methodology

Theory classes
Exercise clases and description of applications

Learning objectives of the subject

At the end of the course, the students should be able to:

- identify the most appropriate approach (rays, waves, photons) for the description of the various phenomena that involve light;
- use the complex notation for describing waves and solving differential equations;
- find the solution to problems of geometric and wave optics, in particular involving the interaction of a planar wavefront with simple optical components (lenses, prisms, mirrors, gratings, etc.);
- describe the working principles behind image-forming optical systems, lasers, semiconductor optoelectronic devices, and telecommunication systems;
- write the rate equations for a laser and calculate its steady-state behavior;
- evaluate the intrinsic limitations of optical instruments and identify alternative strategies to circumvent them; discuss different tools for the analysis and processing of images;
- describe the physical mechanism behind human vision and the challenges for artificial vision.
### Study load

<table>
<thead>
<tr>
<th></th>
<th>Hours large group:</th>
<th>Hours medium group:</th>
<th>Hours small group:</th>
<th>Guided activities:</th>
<th>Self study:</th>
</tr>
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<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>75h</td>
<td>0h</td>
<td>30h</td>
<td>0h</td>
<td>45h</td>
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<td></td>
<td>45h</td>
<td>60.00%</td>
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## Content

<table>
<thead>
<tr>
<th>Electromagnetic waves and optical phenomena</th>
<th>Learning time: 38h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 9h 30m</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 7h 30m</td>
</tr>
<tr>
<td></td>
<td>Self study: 21h</td>
</tr>
</tbody>
</table>

### Description:
- Maxwell's equations and electromagnetic wave equations; invariance of the frequency, Snell's law, vacuum wavelength and the electromagnetic spectrum
- The mathematics of optical waves: plane and spherical waves, complex notation; propagation of plane waves, (linear) light polarization
- Classical sources of radiation: electric-dipole antenna (emitter and receiver), the microwave, the synchrotron
- Optical properties and phenomena in material media and at their interfaces; complex refractive index, group and phase velocity, scattering; reflection, refraction, mirages, dispersion, interference and diffraction; polarizers; antireflection coatings; negative-index metamaterials
- Waveguides, optical fibers, telecom optics

Developed skills: CE1, CE2

### Related activities:
- First round of homework problems (10% of the final mark)
- Second round of homework problems (10% of the final mark)
- Midterm Exam (35% of final mark)

### Specific objectives:
At the end of the first half of the course, students will be able to describe wave phenomena of light identify, to use the complex notation for describing waves and their superposition and solving differential equations; to calculate interference patterns and frequency spectra; and determine the propagation of light through materials, the reflection and refraction of light at their interfaces, and describe the propagation of light inside waveguides and optical fibers.
## Images, laser and optoelectronics

<table>
<thead>
<tr>
<th>Learning time: 37h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 7h 30m</td>
</tr>
<tr>
<td>Practical classes: 6h 30m</td>
</tr>
<tr>
<td>Self study: 23h</td>
</tr>
</tbody>
</table>

### Description:
- Photons, spontaneous and stimulated emission, absorption
- Quantum light sources: thermal sources; amplification, laser theory, types and applications of lasers
- Optoelectronic devices; photodiode, light-emitting devices (LED) and solar cells; detectors and displays
- Optical microscope, telescope, resolution limit; evanescent waves and near-field microscopy (SNOM)
- Dark-field microscopy; holography
- Human and artificial vision
- Image analysis (Fourier filters)

Developed skills: CE11, CE2

### Related activities:
- Third round of homework problems (10% of final mark)
- Final Exam (35% of final mark)

### Specific objectives:
At the end of this section the students will know how to describe the working principles behind semiconductor optoelectronic devices, and their application in telecommunication systems; write the rate equations for a laser and calculate its steady-state behavior; determine the effects induced by optical fields of high intensity; evaluate the intrinsic limitations of optical instruments; compare different techniques for the acquisition and processing of images; describe the physical basis for human vision and the open challenges towards artificial vision.
Planning of activities

**CONTINUOUS ASSESSMENT EXAM (MIDTERM EXAM)**

**Description:** Two-hour exam on the contents of topic 1 and the first part of topic 2.

**Support materials:** transparencies used by teacher for the theory and exercise classes; problems solved in class and autonomously at home; textbook.

**Descriptions of the assignments due and their relation to the assessment:** Evaluated material: exam handed in by student

**Specific objectives:** In this exam the students will be required to solve some optics exercises, stating with clarity the approach used. This will allow the teacher to verify the students’ knowledge of the fundamental concepts of electromagnetic optics.

**Handed-in Homework (3 rounds)**

**Description:** The students will have to hand a series of homework problems, similar to the ones solved in the classroom (two or three for each round).

**Support materials:** Slides used by teacher in class; problems solved in class; textbook.

**Descriptions of the assignments due and their relation to the assessment:** Evaluated material: handed-in homework

**Specific objectives:** Students will learn to describe optical phenomena in terms of the theory explained during class; this will be helpful for them to pass the midterm exam.

Qualification system

The final mark will be a weighted average over the marks obtained in the mid-term, and final exams, as well as on the handed-in homework. The relative weight of each of these marks for the final mark is reported in the table below:

- Mid-term exam 35%
- Homework 30% (10% + 10% + 10%)
- Final exam 35%

If a student scores higher than 6 out of 10 in her/his midterm exam, she/he is exempted from taking the final exam. The final mark, in such a case, will be calculated using the following weights:

- Mid-term exam 70%
- Homework 30% (10% + 10% + 10%)
240407 - Technology of Light

Bibliography

Basic:


Complementary:


Others resources:


- The last chapters of the book by P. Lorrain and D. R. Corson, Campos y ondas electromagnéticas. 5ª Ed., Seleciones Científicas (1990), contain a lot of material on antennas and electromagnetic waves. Several copies are available in the ETSEIB library.