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

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
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Study load

<table>
<thead>
<tr>
<th>Total learning time: 75h</th>
<th>Hours large group: 0h</th>
<th>0.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group: 30h</td>
<td>40.00%</td>
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<tr>
<td></td>
<td>Hours small group: 0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Guided activities: 0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Self study: 45h</td>
<td>60.00%</td>
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</tbody>
</table>
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## Content

<table>
<thead>
<tr>
<th>Electromagnetic waves and optical phenomena</th>
<th>Learning time: 38h</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 9h 30m</td>
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<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 d’Alembert’s equation; the electromagnetic spectrum
- The mathematics of optical waves: plane and spherical waves, complex notation; propagation of planar waves, (linear) light polarization, group and phase velocity
- Classical sources of radiation: electric-dipole antenna (emitter and receiver), the microwave, the synchrotron
- Optical regime (geometric, wave, diffusive, quantum) as a function of the size of a structure and of the wavelength; propagation through vacuum and linear homogeneous media; reflection (mirror), refraction (lens), dispersion (prism), interference and diffraction; diffusion (scattering); polarizers; optics of thin films (interference filters; antireflection coatings); optical fibers
- Developed skills: CE1, CE2

### Related activities:
- Planned activities:
  - First round of homework problems (10% of the final mark)
  - Midterm Exam (40% 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 optical fibers.
## Images, laser and optoelectronics

**Learning time:** 37h  
Theory classes: 7h 30m  
Practical classes: 6h 30m  
Self study: 23h

<table>
<thead>
<tr>
<th>Description:</th>
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</thead>
</table>
| - 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; telecommunications  
- Optical microscope, telescope, resolution limit; evanescent waves and near-field microscopy (SNOM)  
- Dark-field microscopy; holografy  
- Human and artificial vision  
- Image analysis (Fourier filters)  |

**Related activities:**  
Planned activities:  
- Second round of homework problems (10% of the 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) | Hours: 12h
|                                      | Self study: 12h |

**Description:**
Exam of 90 minutes duration on the contents of topic 1.

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

**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 (1 and 2) | Hours: 4h
|                             | Self study: 4h |

**Description:**
The students will have to hand in 6 homework problems (three for each topic).

**Support materials:**
- Slides used by teacher in class;
- problems solved in class;
- text book.

**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.

Qualification system

The final mark received by each student 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 40%
- Homework 20% (10% + 10%)
- Final exam 40%
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Bibliography

Basic:


Complementary:


Others resources:

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

On the webpage: http://alqua.tiddlyspace.com/ students can download lecture notes of several university courses, in particular:

  (a good introduction to optical wave phenomena)

  (an advanced source that contains a detailed description of laser theory)


For some of the themes of topics 2 and 3, the teacher will make use of scientific articles and reviews published on journals to which the UPS has a subscription, as well as of book chapters of specialized books, such as for example the book by B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd Ed., Wiley (2007), which contains a discussion of optical telecommunication technology, optoelectronics (lasers and semiconductor devices), electro-optics and non-linear optics.