Course guide
370007 - OPTIFIS - Wave Optics

Last modified: 20/03/2024

Unit in charge: Terrassa School of Optics and Optometry
Teaching unit: 731 - OO - Department of Optics and Optometry.

Degree: BACHELOR'S DEGREE IN OPTICS AND OPTOMETRY (Syllabus 2020). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Vega Lerin, Fidel
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Others: Armengol Cebrián, Jesus
https://futur.upc.edu/JesusArmengolCebrian
Perez Cabre, Elisabet
https://futur.upc.edu/ElisabetPerezCabre

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE04. (ENG) The ability to understand the process of image formation and the properties of optical systems. The ability to understand aberrations in optical systems. The ability to understand radiometric and photometric fundamentals and laws.
CE07. (ENG) The ability to understand and manage basic laboratory materials and techniques.
CE08. (ENG) The ability to understand light propagation in isotropic media, light-matter interactions, light interference, diffraction phenomena, the properties of single- and multi-layer surfaces and the principles and applications of lasers.

Generical:
CG11. Locate new information and interpret it in context.

CG13. Demonstrate and interpret methods for critical analysis and theory development and apply them to the field of optometry.

Transversal:
CT5. Efficient use of informacion resources. To manage data and technical and scientific information adquisition, organization, analysis and visualization and to provide a critical appraisal of the results of this management

TEACHING METHODOLOGY

In the course, we aim to combine lectures with informal, cooperative learning activities and problem solving, and in laboratory sessions, to work in small, stable groups.

LEARNING OBJECTIVES OF THE SUBJECT

The course focuses on the use of geometrical, electromagnetic and quantum optics to study light phenomena related to the nature of light, its production, its propagation and its interaction with matter.
Upon finishing the Wave Optics course, students must have acquired the following (taken from the Official Gazette of the Spanish Government):
- The ability to understand and use basic laboratory equipment and techniques.
- The ability to understand light propagation in isotropic media, light-matter interaction, light interference, diffraction phenomena, the properties of single- and multi-layer surfaces and the principles and applications of lasers.
- The ability to understand the principles, descriptions and characteristics of basic optical instruments and the instruments used in optometric and ophthalmic practice.
- The ability to understand radiometric and photometric fundamentals and laws.
- The ability to understand the factors that limit retinal image quality.

STUDY LOAD

Type	Hours	Percentage
Self study	90,0	60.00
Hours medium group	45,0	30.00
Hours small group	15,0	10.00

Total learning time: 150 h

CONTENTS

1. Light is an electromagnetic wave

Description:
1.1. Brief review of waves. Plane waves in isotropic dielectric media.
1.2. Electromagnetic waves.
1.3. Energy of electromagnetic waves.
1.4. Light propagation in a vacuum and in dielectric media.

Specific objectives:
Objectives: light is a transverse electromagnetic wave.
- To define the following parameters (with appropriate units): amplitude, wavelength, frequency and period, velocity, the initial phase, characteristics of an electromagnetic wave.
- To determine the directions of propagation and vibration of the E-field and B-field that make up light and the relationship between their amplitudes.
- To write the equation for the E-field and B-field that make up a light wave (with their model and directions of vibration and propagation) correctly.
- To calculate the irradiance of a wave and the relationship of the wave to radiant flux (power).
- To identify the order of magnitude of the wavelength of visible light.

Related activities:
Laboratory practicals
Practical 0. Introductory session.

Full-or-part-time: 18h
Practical classes: 4h
Laboratory classes: 2h
Self study : 12h

2. Light propagation in dielectric and isotropic media

Description:
2.1. Reflection and refraction of light in dielectric and isotropic media. Fresnel equations.
2.2. Reflectance and transmittance.

Specific objectives:
R and T objectives:
- To differentiate external reflection from internal.
- To define the plane of incidence.
- To determine if the E of light vibrates parallel or perpendicular to the plane of incidence.
- To understand the definition of and know how to apply the formulae of reflectance and transmittance perpendicular and parallel to the plane of incidence.
- To describe R and T curves as functions of the angle of incidence (in cases of internal and external reflection).
- To define Brewster's angle and the conditions for obtaining it.
- To know how to obtain the reflectance and transmittance of natural light.
- To justify the need for anti-reflective treatments in lenses.

Related activities:
Laboratory practicals:
Practical 1. Measuring perpendicular R and perpendicular T.
Practical 2. Measuring R// and T//. Brewster's angle.
Practical 3. Measuring R// and T// in a metal.

Full-or-part-time: 24h
Practical classes: 5h
Laboratory classes: 7h
Self study : 12h

3. Propagation of light in anisotropic dielectric media. Polarisation of light

Description:
3.1. What does polarisation study?
3.2. Types of polarisation.
3.3. What is a polariser?
3.4. Polarised wave equations.
3.5. Linear polarisers. Ways of obtaining linearly polarised light.
3.6. Waveplates.
3.7. Applications of polarisation (photoelasticity in optics workshops, 3D vision, filters, etc.).

Specific objectives:
Objectives regarding polarisation:
- To explain what polarised light is in precise terms in comparison to natural light.
- To express any kind of polarised light as the sum of two harmonic, orthogonal plane waves, with their correct amplitudes and relative phase changes.
- To explain the four processes for obtaining linearly polarised light from natural light. To know how to calculate the state of polarisation and the irradiance resulting from a wave in systems of two or three linear polarisers.
- To explain the principle behind the working of waveplates. To find the state of polarisation of light using polarisers and waveplates.
- To find and explain applications for polarised light in other contexts and courses in the degree.

Related activities:
Laboratory practicals
Practical 4. Malus’s law.
Practical 5. Lambda/2 waveplate.
Practical 6. Lambda/4 waveplate.

Full-or-part-time: 34h
Practical classes: 7h
Laboratory classes: 7h
Self study : 20h

4. Light wave interference

Description:
4.1. Superposition principle. Wave-particle difference.
- Calculation of the intensity resulting from superimposing two waves.
- Conditions for being able to see interference.
4.2. Wavefront splitting interferometers.
- Young's double slit experiment.
- Interference patterns obtained from white light. Rationale.
4.3. Amplitude splitting interferometers.
- Michelson-Morley interferometer.
- Dielectric films.
4.4. Multilayers and coatings. Different effects in optics and ophthalmic optics.

Specific objectives:
Objectives regarding interference:
- To find the kind of interference between two waves based on their phase difference. Interference term.
- To explain the conditions under which two waves interfere (coherence, same frequencies, etc.).
- To determine, using the space between fringes, wavelength or the distance between slits.
- To represent the irradiance of the interference pattern obtained with a double slit as a function of phase change.
- To explain the interference figure of a double slit with both white and monochromatic light.
- To explain the problem that anti- and super-reflective sheets aim to solve/avoid.
- To find the phase difference in thin sheets in cases with near-normal incidence.
- To define the proper index of a sheet depending on the glass that it is to cover, so that it will have an anti- or super-reflective effect.
- To determine the width of a thin sheet based on interference maxima and/or minima.
- To explain the dependence of the state of interference on wavelength.

Related activities:
Laboratory practicals
Practical 7. Young's double slit experiment.
Practical 8. Fresnel biprism.
Practical 9. Interference in thin layers.

Full-or-part-time: 34h
Practical classes: 7h
Laboratory classes: 7h
Self study : 20h

5. Diffraction of light

Description:
5.1. Fraunhofer diffraction by simple apertures.
- The Huygens-Fresnel principle.
- Conditions of Fraunhofer diffraction.
- Single-slit diffraction.
- Diffraction by an opaque body. Babinet’s principle.
- Diffraction by a circular aperture.
- The Rayleigh resolution criterion. Diffraction-limited resolution.
- Diffraction patterns of white light.
5.2. Diffraction by 2, 3… N slits. Diffraction grating.
- Two slits. Diffraction figure + two-slit interference.
- Diffraction grating.
- Chromatic resolving power.
5.3. Diffractive intraocular lenses.

Specific objectives:
Objectives regarding diffraction:
- To phenomenologically describe diffraction and understand it as per the Huygens-Fresnel model.
- To describe the forms resulting from Fraunhofer diffraction and those associated with simple geometric apertures (rectangular, circular, double slit and diffraction grating).
- To distinguish between the phenomena of interference and diffraction in systems with multiple slits.
- To calculate the wavelength and measurements of slits based on diffraction patterns.
- To apply Rayleigh’s resolution limit to determine when two points are resolved in image-forming optical systems.
- Diffractive intraocular lenses.

Related activities:
Laboratory practicals
Practical 10. Diffraction by 1, 2… N slits.
Practical 11. Diffraction grating.
Practical 12. Diffraction by a circular aperture.

Full-or-part-time: 34h
Practical classes: 7h
Laboratory classes: 7h
Self study : 20h

ACTIVITIES

European Diploma competencies

Description:
The Wave Optics course contributes fully or partially to Competency 1. Optical waves and aberrations, which is worked on in Topic 1. Light is an electromagnetic wave, with a weight of 1.8 ECTS credits.
The Wave Optics course contributes fully or partially to Competency 2. Light-matter interaction, which is worked on in Topic 2. Propagation of light in isotropic and dielectric media, with a weight of 2.4 ECTS credits.
The Wave Optics course contributes fully or partially to competencies 3. Polarisation and 4. Transmission via consecutive polarisers, which are worked on in Topic 3. Propagation of light in anisotropic, dielectric media. Polarisation of light, with a weight of 3.4 ECTS credits.
The Wave Optics course contributes fully or partially to competencies 5. Image quality and 6. Diffraction and interference, which are worked on in Topic 4. Interference with waves of light and 5. Diffraction of light, with a weight of 6.8 ECTS credits.

GRADING SYSTEM

The evaluation will be based on continuous assessment.
The evaluation of the course is divided between the theory sessions (T) and laboratory (L).
The assessment system will be continuous assessment.
Course assessment is divided between the lectures on theory (T) and laboratory (L) sessions.
The mark for lectures (T) will be calculated using marks for at least two exams. The mark for laboratory practicals will be calculated using marks for at least one practical exams.
The final mark (N) is obtained using the following formula: $N = 0.75\ T + 0.25\ L$
ASSESSMENT OF CROSS-DISCIPLINARY COMPETENCIES: Cross-disciplinary competencies will be considered to have been obtained if the course is passed with a mark of at least 5.
REASSESSMENT: The reassessment will consist of a single exam that may include questions related to theory and/or problems to solve and/or questions about laboratory sessions.

EXAMINATION RULES.

In case of partial or total copy of any evaluations of the course, will apply the provisions of General Academic Regulations
UPC: Irregular actions potentially leading to a significant variation of the marks obtained by one or more students will be considered a breach of the assessment regulations. Such behaviour will result in a descriptive mark of “Fail” and a numerical mark of 0 for the examination in question and the subject, without prejudice to any disciplinary proceedings that may result from that behaviour.
If a student disagrees with this decision, he or she may file a complaint with the dean or director of the school. If the student is not satisfied with the response, he or she may lodge an appeal with the rector.
If copying (either partial or total) is found to have taken place on any course assessment, that which is stipulated in the Academic Regulations for Bachelor's and Master's Degrees at the UPC will apply. Any kind of cheating on any exam will, at the least, result in a mark of 0 for that exam, and possibly in more severe disciplinary action.

“Irregular actions potentially leading to a significant variation of the marks obtained by one or more students will be considered a breach of the assessment regulations. Such behaviour will result in a descriptive mark of “Fail” and a numerical mark of 0 for the examination in question and for the subject, without prejudice to any disciplinary proceedings that may result from that behaviour.

If students disagree with this decision, they may file a complaint with the dean or director of the school. If students are not satisfied with the response, they may lodge an appeal with the rector.

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The director or dean of the school makes decisions regarding allegations about any aspects not covered in the regulations.”

BIBLIOGRAPHY

Basic:
- Hecht, Eugene. Óptica [on line]. 5a ed. Marid: Addison-Wesley Iberoamericana, 2017 [Consultation: 06/05/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=6557. ISBN 8478290257.
- Pedrotti, Leno S; Pedrotti, Frank L. Optics and vision. Upper Saddle River, N.J.: Prentice Hall, cop. 1998. ISBN 0132422239.
- Hewitt, Paul G.; Escalona García, Héctor Javier. Física conceptual [on line]. 12ª ed. México [etc.]: Pearson, 2016 [Consultation: 10/05/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=6757. ISBN 9786073238182.
- Tipler, Paul Allen; Mosca, Gene. Física per a la ciència i la tecnologia, vol. 1 [on line]. Barcelona [etc.]: Reverté, 2010 [Consultation: 06/05/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=5758258. ISBN 9788429144321.

Complementary:
- Pedrotti, Frank L.; Pedrotti, Leno M.; Pedrotti, Leno S. Introduction to optics. 3rd ed. San Francisco: Pearson Prentice-Hall, cop. 2007. ISBN 9780131499331.
- Meyer-Arendt, Jurgen R. Introduction to classical and modern optics. 4th ed. Englewood Cliffs: Prentice-Hall International, cop.

1995. ISBN 013124356X.
- Carreño, Fernando; Antón, Miguel Ángel. Óptica física : problemas y ejercicios resueltos. Madrid [etc.]: Prentice Hall, cop. 2001. ISBN 8420531812.
- Vázquez, Carmen [et al.]. Óptica física : cuestiones y problemas. Alicante: Universidad de Alicante, cop. 2006. ISBN 8479088613.
- Calvo Padilla, María Luisa. Óptica avanzada. Barcelona: Ariel, 2002. ISBN 8434480522.

RESOURCES

Other resources:
Software and videos available on the intranet and library.