2022/2023

Optics

Code: 100156
ECTS Credits: 9

Degree	Type	Year	Semester
2500097 Physics	OB	3	A

Contact

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Use of Languages

Principal working language: spanish (spa)
Some groups entirely in English: No
Some groups entirely in Catalan: No
Some groups entirely in Spanish: Yes

Other comments on languages

Theory classes in Spanish, problem classes in Catalan.

Teachers

Juan Ignacio Pedro Campos Coloma

Prerequisites

There are no special requirements, but it would be convenient if the student has completed the subjects of Electromagnetisme, Ones i Òptica, and those related to mathematics fundamentals given at previous academic courses.

Objectives and Contextualisation

The general goal of the Òptica subject is to present to students a general view of the classical optics field, which encompasses a wide range of knowledge areas, from optical instrumentation to interferential and diffraction phenomena. The quantum optics theory is addressed within another subject of the physics degree. The Òptica subject, in addition to provide basic knowledge in the optics field, it is also useful to illustrate how different phenomena can be described by using different theoretical models: electromagnetic model, wave model, geometrical model, etc. This approach meets a transversal competence of learning how to identify a problem, and considering the most suitable methodology to solve it.

The Òptica subject is highly interrelated with the Laboratori d'Òptica subject, which is taught in the same academic course and presents an experimental approach of the Optics phenomena, forming up a thematic cluster.

By means of the geometrical model, the knowledge required to understand the basic optical instruments is provided: Human eye, photographic camera, telescope, and the microscope. By means of the light electromagnetic theory, the interaction of light with different materials is studied, taking special attention to isotropic media and to anisotropic homogeneous and linear media. Regarding to dielectric materials, the classical Lorentz model is introduced to explain the dispersion phenomenon. Finally, by means of the wave model, interferential and diffraction phenomena are studied.

Competences

- Develop strategies for analysis, synthesis and communication that allow the concepts of physics to be transmitted in educational and dissemination-based contexts
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Know the fundamentals of the main areas of physics and understand them
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation

Learning Outcomes

1. Apply the Fourier transform to describe and polychromatic waves and to describe the phenomenon of diffraction.
2. Assess the resolution of optical systems taking size into consideration.
3. Calculate the direction of propagation for waves transmitted in anisotropic media.
4. Calculate the energy carried by a beam.
5. Calculate the figure of diffraction produced by different apertures, applying the approaches necessary.
6. Calculate the interference pattern produced in different interferometers and determine changes in the figure when varying certain system parameters.
7. Calculate the refraction of a plane wave in anisotropic medium and the divergence produced.
8. Calculate the waves transmitted and reflected in an interface between two isotropic media and assess their state of polarization.
9. Describe induced polarization in a dielectric medium and the complex refractive index.
10. Describe methods to evaluate the diffraction produced by different apertures.
11. Describe the Maxwell equations and the obtention, from these, of the equation of electromagnetic waves.
12. Describe the classical Lorentz model of light-matter interaction.
13. Describe the conditions of propagation for a wave in an anisotropic medium (ordinary and extraordinary wave).
14. Describe the conditions required for stable interference to occur.
15. Describe the effects that modify the index ellipsoid of a material.
16. Describe the functioning of retardant plates.
17. Describe the main types of wave fronts and the harmonic solution of wave equation.
18. Describe the phenomena of refraction and reflection in isotropic media.
19. Describe the phenomenon of light diffraction.
20. Describe the polarization states of light.
21. Describe the various devices to produce interference.
22. Determine the state of polarization of a beam before and after crossing a retarding plate.
23. Identify optical phenomena observed in nature and explain them clearly in non-specialized settings.
24. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
25. Use the complex representation of harmonic waves.
26. Use wave equation and its general solutions.

Content

1. Waves:
    1. Wave motion equation. Plane waves, spherical waves.
    2. Harmonic solution of the wave equation. Fourier analysis.
    3. Superposition of waves with the same frequency.
    4. Superposition of waves with different frequency. Phase and group velocities.

    5. Superposition of waves with orthogonal electric fields.
3. Light electromagnetic theory. Electromagnetic waves:
    1. Macroscopic Maxwell equations. Material response. Energy relations.
    2. Electromagnetic waves. Linear, homogeneous and isotropic media. Transverse characteristic of plane waves. Energy transport.
5. Isotropic media:
    1. Reflection and refraction at dielectric interface. Fresnel equations.
    2. Dielectric media. Induced polarization. Classical Lorentz model for the dipole description.
    3. Propagation and diffusion of a light beam.
7. Geometrical Optics. Paraxial approximation:
    1. Fermat principle. Ray trajectory equation. Light propagation in non-uniform media.
    2. Imaging with geometrical optics.
    3. Paraxial optics. Abbe's invariant. Magnification.
    4. Composed optical systems. Focal points and focal planes. Principal points and principal planes. Thick lenses. Coupled optical systems.
9. Optical instrumentation:
    1. Human eye.
    2. Photographic systems and projectors.
    3. Telescopes.
    4. Near vision instruments: Magnifying glass, optical microscope.
11. Anisotropic media. Polarization:
    1. Electrical susceptibility. Indices ellipsoid.
    2. Wave equation in anisotropic media. Propagation conditions.
    3. Light refraction in an anisotropic media. Fresnel construction. Indices ellipsoid construction.
    4. Absorbing anisotropic media.
13. Interferences:
    1. General principles. Conditions for interferences.
    2. Wave front division interferences: Young interference pattern, practical arrangements.
    3. Amplitude division interferences. Michelson interferometer.
    4. Interference produced by multiple light beams obtained by amplitude division. Fabry-Perot interferometer.
15. Diffraction:
    1. Huygens-Fresnel principle.
    2. Fresnel and Fraunhoffer diffraction approaches.
    3. Fraunhoffer diffraction produced by a single aperture: single slit, rectangular aperture, circular aperture. Instruments resolution power.
    4. Fraunhoffer diffraction produced by diverse apertures: Double slit, diffraction grating.
    5. Introduction to the Kirchhoff scalar theory.

Methodology

THEORETICAL CLASSES

Within this type of activity the theoretical concepts of the course will be provided. Those slides used during the course will be uploaded to the virtual campus.

Students will be encouraged to participate and to ask questions related to doubts that may rise by using the subjects forum at the virtual campus. In addition, professors will ask questions to them in order to evaluate their comprehension of the knowledge taught.

PRACTICAL CLASSES

These classes will be used to put into practice the concepts described at the theory classes, with the aim of identifying the type of problem to be solved, and the more suitable methodology to be applied to resolve it. The problems statements will be uploaded at the Campus Virtual well in advance, in order to students can try to solve them before the resolution is described at class, and thus, they can ask their doubts in the corresponding problem session.

PHOTOGRAPHS DELIVERY

This activity is performed with the aim of enhancing the observation capacity of students and to foster their capability to relate phenomena present in the nature with the concepts taught in the Òptica subject.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Problems sessions	25	1	1, 2, 4, 3, 6, 5, 7, 8, 19, 16, 12, 21, 15, 20, 18, 10, 17, 9, 13, 14, 11, 22, 24, 25, 26
Theory sessions	50	2	1, 2, 4, 3, 6, 5, 7, 8, 19, 16, 12, 21, 15, 20, 18, 10, 17, 9, 13, 14, 11, 22, 24, 25, 26
Type: Supervised			
Photographs of optical phenomena in the nature	5	0.2	23, 24
tutorship	4.5	0.18	24
Type: Autonomous			
Problems solving	51	2.04	1, 2, 4, 3, 6, 5, 7, 8, 22, 24, 25, 26
Self-study	80	3.2	19, 16, 12, 21, 15, 20, 18, 10, 17, 9, 13, 14, 11, 24

Assessment

The assessment of the subject will be conducted as following:

- Writing tests (90%)
  - First partial test or remedial first test (45%)
  - Second partial test or remedial second test (45%)
- Photographs of optical phenomena (10%)

WRITING TESTS

These tests are aimed to evaluate the knowledge acquired by students, as well as their capability of analysis, synthesis and reasoning.

WRITING PARTIAL TESTS

Two partial tests will be conducted. The contents evaluated in each partial will be those present in the topics covered during the corresponding periods of the course. The partial dates will be announced well in advance.

Students who have passed the partials are not required to take the final remedial exam. Each one of these two tests accounts for the 45% of the final subject mark.

To opt for the evaluation (the average between the two partial marks), it is required a minimum mark of 4 up to 10 in each partial.

FINAL WRITING TEST

It comprises two parts, each one corresponding to the above-stated partial tests.

Students that have not pass, or not conducted, any of the two partials, have to conduct the corresponding remedial part of the final writing test.

If a student has already passed one of the partials, she/he has also the option to conduct the corresponding remedial part in the final writing test.

Under this scenario, the final mark will be that achieved in the final part test, independently of the mark she/he had taken in the previous partial.

PHOTOGRAPHS OF OPTICAL PHENOMENA

In this section, the observation capacity of the student will be evaluated and the concepts studied will be related to natural phenomena.
Each student must present 6 original photographs (made by themselves) of natural phenomena related to the concepts studied in the subject. No photos obtained in the laboratory, nor downloads from the internet (in this case the note corresponding to the photos will be 0). In addition, you must give a brief explanation (about a sheet) of the phenomenon analyzed.
Each of the 6 photographs must be dedicated to a different phenomenon. 3 pictures will be presented online at the end of each semester (before the corresponding partial exam) in pdf or word format.
The name of the files will be: Name_Surname_n ...
n will be equal to 1 or 2 depending on the delivery of the first semester or the second semester.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
1er Partial examination	45	2.5	0.1	1, 2, 4, 8, 12, 20, 18, 17, 9, 11, 24, 25, 26
2n Partial examination	45	2.5	0.1	3, 6, 5, 7, 19, 16, 21, 15, 10, 13, 14, 22, 24
Partials remedial exam	90	3.5	0.14	1, 2, 4, 3, 6, 5, 7, 8, 19, 16, 12, 21, 15, 20, 18, 10, 17, 9, 13, 14, 11, 22, 24, 25, 26
Photographs delivery	10	1	0.04	23, 24

Bibliography

THEORY BOOKS

- J. Casas. Óptica. Universidad de Zaragoza
- E. Hecht. Optics. Addison-Wesley Publishing Company.
- M.V. Klein, T. E. Furtak. Optics. John Wiley & Sons
- Keigo Iizuka, Elements of Photonics Volume 1. John Wiley & Sons, Inc. ISBNs: 0-471-83938-8 (Hardback); 0-471-22107-4 (Electronic)
- R. Guenter. Modern Optics. John Wiley & Sons
- B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics, second edition. John Wiley & Sons. ISBN: 978-0-471-35832-9
- F.G. Smith, J.H. Thomson, Optics, John Wiley & Sons Ltd. ISBN 0 471 91534 3

PROBLEMS BOOKS

- E. Hecht. Teoría y Problemas de Óptica. MacGraw-Hill
- M. López, J.L. Díaz, J.M. Jiménez. Problemas de Física volumen V. Óptica. Editorial Romo.
- M. Fogiel, THE OPTICS PROBLEM SOLVER, Research and Education Association. ISBN: 0-87891-526-5
- Lim Yung-kuo, Problems and Solutions on Opticsm. World Scientific. ISBN: 981-02-0438-8

ELECTRONIC RESOURCES

Optic's Applets in java: http://www.ub.es/javaoptics/index-en.html

Physics' Applets in java: http://www.walter-fendt.de/ph14s/

Virtual Campus: Applets in LabView and videos related to some optics phenomena

Software

Applets of optical phenomena in Matlab