

Facultad de Ciencias

Grado en Física

GUÍA DOCENTE DE LA ASIGNATURA (ESCENARIO 1):

Dinámica de Fluidos Astrofísicos (2021 - 2022)

1. Datos descriptivos de la asignatura

Asignatura: Dinámica de Fluidos Astrofísicos	Código: 279190901
- Centro: Facultad de Ciencias - Lugar de impartición: Facultad de Ciencias - Titulación: Grado en Física - Plan de Estudios: 2009 (Publicado en 2009-11-25) - Rama de conocimiento: Ciencias - Itinerario / Intensificación: - Departamento/s: Astrofísica - Área/s de conocimiento: Astronomía y Astrofísica - Curso: 4 - Carácter: Optativo - Duración: Primer cuatrimestre - Créditos ECTS: 6,0 - Modalidad de impartición: Presencial - Horario: Enlace al horario - Dirección web de la asignatura: http://www.campusvirtual.ull.es - Idioma: Castellano e Inglés (60% en inglés). La asignatura participa en el programa FINULL	

2. Requisitos para cursar la asignatura

Necesario tener aprobado al menos 90 créditos.

Recomendación: contar con al menos el nivel B1 de inglés para garantizar el seguimiento efectivo de la docencia

3. Profesorado que imparte la asignatura

Profesor/a Coordinador/a: FERNANDO MORENO INSERTIS
- Grupo:
General - Nombre: FERNANDO - Apellido: MORENO INSERTIS - Departamento: Astrofísica - Área de conocimiento: Astronomía y Astrofísica

Contacto

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- Correo alternativo:
- Web: **<http://www.campusvirtual.ull.es>**

Tutorías primer cuatrimestre:

Desde	Hasta	Día	Hora inicial	Hora final	Localización	Despacho
27-09-2021	22-12-2021	Lunes	12:00	13:30	Edificio de Física y Matemáticas - AN.2B	Departamento Astrofísica
27-09-2021	22-12-2021	Martes	12:00	13:30	Edificio de Física y Matemáticas - AN.2B	Departamento Astrofísica
27-09-2021	22-12-2021	Miércoles	12:00	13:30	Edificio de Física y Matemáticas - AN.2B	Departamento Astrofísica
27-09-2021	22-12-2021	Jueves	12:00	13:30	Edificio de Física y Matemáticas - AN.2B	Departamento Astrofísica
10-01-2022	09-02-2022	Lunes	13:00	14:30	Edificio de Física y Matemáticas - AN.2B	Departamento
10-01-2022	09-02-2022	Martes	13:00	14:30	Edificio de Física y Matemáticas - AN.2B	Departamento
10-01-2022	09-02-2022	Miércoles	13:00	14:30	Edificio de Física y Matemáticas - AN.2B	Departamento
10-01-2022	09-02-2022	Jueves	13:00	14:30	Edificio de Física y Matemáticas - AN.2B	Departamento

Observaciones:

Tutorías segundo cuatrimestre:						
Desde	Hasta	Día	Hora inicial	Hora final	Localización	Despacho
Todo el cuatrimestre		Jueves	10:00	13:00	Instituto de Astrofísica de Canarias - EX.1A IAC	
Todo el cuatrimestre		Viernes	10:00	13:00	Instituto de Astrofísica de Canarias - EX.1A IAC	
Observaciones:						

4. Contextualización de la asignatura en el plan de estudio

Bloque formativo al que pertenece la asignatura: **Física Optativa**
 Perfil profesional:

5. Competencias

Competencias Generales

CG1 - Conocer el trabajo en el laboratorio, el uso de la instrumentación, tecnología y métodos experimentales más utilizados, adquiriendo la habilidad y experiencia para realizar experimentos de forma independiente. Ello le permitirá ser capaz de observar, catalogar y modelizar los fenómenos de la naturaleza.

CG3 - Desarrollar una clara percepción de situaciones aparentemente diferentes pero que muestran evidentes analogías físicas, lo que permite la aplicación de soluciones conocidas a nuevos problemas. Para ello es importante que el alumnado, además de dominar las teorías físicas, adquiera un buen conocimiento y dominio de los métodos matemáticos y numéricos mas comúnmente utilizados.

CG4 - Desarrollar la habilidad de identificar los elementos esenciales de un proceso o una situación compleja que le permita construir un modelo simplificado que describa, con la aproximación necesaria, el objeto de estudio y permita realizar predicciones sobre su evolución futura. Así mismo, debe ser capaz de comprobar la validez del modelo introduciendo las modificaciones necesarias cuando se observen discrepancias entre las predicciones y las observaciones y/o los resultados experimentales.

CG5 - Conocer las posibilidades de aplicar la Física en el mundo laboral, docente y de investigación, desarrollo tecnológico e innovación y en las actividades de emprendeduría

CG6 - Saber organizar y planificar el tiempo de estudio y de trabajo, tanto individual como en grupo; ello les llevará a aprender a trabajar en equipo y a apreciar el valor añadido que esto supone.

CG7 - Ser capaz de participar en debates científicos y de comunicar tanto de forma oral como escrita a un público especializado o no cuestiones relacionadas con la Ciencia y la Física. También será capaz de utilizar en forma hablada y escrita otro idioma, relevante en la Física y la Ciencia en general, como es el inglés.

CG8 - Poseer la base necesaria para emprender estudios posteriores con un alto grado de autonomía, tanto desde la formación científica, (realizando un master y/o doctorado), como desde la actividad profesional.

Competencias Básicas

CB2 - Que los estudiantes sepan aplicar sus conocimientos a su trabajo o vocación de una forma profesional y posean las competencias que suelen demostrarse por medio de la elaboración y defensa de argumentos y la resolución de problemas dentro de su área de estudio

CB3 - Que los estudiantes tengan la capacidad de reunir e interpretar datos relevantes (normalmente dentro de su área de estudio) para emitir juicios que incluyan una reflexión sobre temas relevantes de índole social, científica o ética

CB4 - Que los estudiantes puedan transmitir información, ideas, problemas y soluciones a un público tanto especializado como no especializado

CB5 - Que los estudiantes hayan desarrollado aquellas habilidades de aprendizaje necesarias para emprender estudios posteriores con un alto grado de autonomía

Competencias Específicas

CE4 - Conocer los hitos más importantes de la historia del pensamiento científico y de la Física en particular.

CE5 - Desarrollar una visión panorámica de la Física actual y sus aplicaciones

CE6 - Tener un buen conocimiento sobre la situación en el momento presente en, por lo menos, una de las especialidades actuales de la física.

CE7 - Comprobar la interrelación entre las diferentes disciplinas científicas

CE11 - Adquirir destreza en la modelización matemática de fenómenos físicos.

CE12 - Observar fenómenos naturales y realizar experimentos científicos.

CE13 - Registrar de forma sistemática y fiable la información científica.

CE14 - Analizar, sintetizar, evaluar y describir información y datos científicos

CE15 - Medir magnitudes esenciales en experimentos científicos.

CE16 - Evaluar y analizar cuantitativamente los resultados experimentales

CE17 - Realizar informes sintetizando los resultados de experimentos científicos y sus conclusiones más importantes.

CE18 - Utilizar la instrumentación científica actual y conocer sus tecnologías innovadoras.

CE19 - Desarrollar la "intuición" física.

CE20 - Utilizar herramientas informáticas en el contexto de la matemática aplicada.

CE23 - Ser capaz de evaluar claramente los órdenes de magnitud, así como de desarrollar una clara percepción de las situaciones que son físicamente diferentes, pero que muestran analogías, permitiendo el uso de soluciones conocidas a nuevos problemas.

CE24 - Afrontar problemas y generar nuevas ideas que puedan solucionarlos

CE25 - Ser capaces de realizar experimentos de forma independiente.

CE26 - Dominar la expresión oral y escrita en lengua española, y también en lengua inglesa, dirigida tanto a un público especializado como al público en general.

CE27 - Haber desarrollado habilidades para la popularización de las cuestiones concernientes a la cultura científica y de aspectos aplicados a la física clásica y moderna.

CE28 - Adquirir hábitos de comportamiento ético en laboratorios científicos y en aulas universitarias.

CE29 - Organizar y planificar el tiempo de estudio y trabajo, tanto individual como en grupo.

CE30 - Saber discutir conceptos, problemas y experimentos defendiendo con solidez y rigor científico sus argumentos.

CE31 - Saber escuchar y valorar los argumentos de otros compañeros.

CE32 - Saber trabajar e integrarse en un equipo científico multidisciplinar

CE33 - Ser capaz de identificar lo esencial de un proceso / situación y establecer un modelo de trabajo del mismo.

6. Contenidos de la asignatura

Contenidos teóricos y prácticos de la asignatura

PRELIMINARY NOTES:

(1). The program contains a number of optional complementary topics. They will be offered to the students depending on the general progress of the main topics of the course and, also, on the interest of the students.

(2) the optional practicals are of a simple numerical nature and will be carried out by programming using the Python language. The students will be offered, typically, one or two such practicals along the course.

Chapter 1 – THE DESCRIPTION OF A CONTINUOUS AND DEFORMABLE MEDIUM

1.1 – The Euler and Lagrange descriptions: multidimensional maps versus fluid element tracking. The Lagrange derivative.

1.2 – The relative motion of neighboring fluid elements. The expansion, rotation and strain tensors.

1.3 – Mass, momentum and energy of finite volumes and parcels of fluid. Volume forces and surface forces.

Optional numerical practical:

- fluid element tracking in a two-dimensional map.

Chapter 2 – THE CONSERVATION LAWS FOR AN IDEAL FLUID

2.1 – The variation in time of integrated quantities in finite fluid parcels: Reynolds Theorem

2.2 – The mass conservation law (i.e., the continuity equation). Precise definition of the concepts 'volume density' and 'flux across surfaces' of physical quantities.

2.3 – The momentum equation

2.4 – The total energy equation. Separation into equations for the kinetic and internal energy. The natural combination of mechanics and thermodynamics occurring in a fluid.

2.5 – The canonical conservation form for the equations of a continuous medium.

2.6 – Closure of the system of equations. Their intrinsically non-linear character.

Chapter 3 - IDEAL FLUIDS

3.1 - Euler equation

3.2 – Motion around obstacles. The classical potential flow problem. Ram pressure.

3.3 – Compressible motion: astrophysical example. The solar wind.

3.4 – Vorticity. Kelvin's circulation theorem.

Optional complementary topics

- Aerodynamics. The lift force on aerodynamic profiles: Kutta-Zhukovski theorem. The Zhukovski transformation and the Kutta condition for the flow around wings.
- The static equilibrium of a gas sphere: stellar interiors.

Optional numerical practicals:

- Calculation of aerodynamic profiles. Lift force on actual aeroplanes. Force on windmill blades.
- The motion of the gas in solar coronal loops. Subsonic and supersonic regimes. Mach numbers.
- The numerical calculation of Parker's solar wind solution including the sonic point and the sub- and supersonic regimes.
- The numerical solution of partial differential equations: heat conduction.
- The numerical solution of partial differential equations: the continuity equation.

Chapter 4 – THE MICROSCOPIC FOUNDATIONS OF THE FLUID EQUATIONS

- 4.1 – The continuum approximation: the criterion of scale separation in space and time. Local thermodynamic equilibrium.
- 4.2 – Statistical averages and macroscopic fluid quantities. The bulk kinetic energy of the flow. The internal energy due to the translational degrees of freedom.
- 4.3 – The calculation of pressure and viscosity in kinetic theory: elementary considerations.
- 4.4 – The entropy equation. Entropy flux. Sources and sinks of entropy. Irreversible processes in fluids. Irreversibility in thermodynamics and irreversibility in fluid dynamics.

Chapter 5 - VISCOSITY.

- 5.1 – Surface forces. Stress tensor. Cauchy theorem.
- 5.2 – The momentum equation for a generic stress tensor.
- 5.3 – The viscous stress tensor as a microscopic transport phenomenon. Newtonian fluids.
- 5.4 – The Navier-Stokes equation. Reynolds number.
- 5.5 – The energy equation for the viscous case. The irreversible heating through viscosity.

Optional complementary topics:

- Electromagnetism and fluid dynamics. The Maxwell stress tensor. Electromagnetic pressure and tension. Volume density and flux of the electromagnetic energy.
- Boundary layers
- Accretion discs around astrophysical objects.
- The flux density four-vector in Einstein's relativity theory. The stress-energy tensor and the conservation laws for relativistic fluids.

Chapter 6 – Linear waves in gases

- 6.1 – Perturbation treatment of the non-linear equations. Linearization of the gas equations. Pressure waves (also known as sound waves).
- 6.2 – Fourier analysis. Eigenvalue equation. Dispersion relation. The eigenvectors as normal modes.
- 6.3 – Sound waves of finite amplitude. The nonlinearity and the spontaneous transition to shock waves.

Optional complementary topics:

- Inhomogeneous equilibrium. The WKB approximation. Phase speed and group speed. Ray tracing: geometrical acoustics.

– Gravity waves in stellar interiors.

Optional numerical practicals:

- normal mode decomposition of initial perturbations in a one-dimensional problem.
- Ray tracing of sound waves in an inhomogeneous gas.

Chapter 7 – SHOCK FRONTS

7.1 – Shock fronts: a ubiquitous and unavoidable phenomenon in the Universe.

7.2 – Conservation equations across a shock front. The Rankine-Hugoniot jump conditions. Mach numbers: supersonic and subsonic regimes.

7.3 – Weak shocks. Strong shocks: thermalization of the incoming kinetic energy flux.

7.4 – Examples: explosions in general. Supernova remnants. Accretion columns on white dwarf stars or neutron stars.

Optional complementary topic:

- The transmission of information in gases. Characteristic curves. The shock fronts as the natural, inescapable result of compressions in gases.

Optional numerical practical:

- gas element tracking across a shock.

Actividades a desarrollar en otro idioma

- All written material given by the lecturer to the students will be in English, including all course notes, the exercise and auxiliary sheets, practical scripts, computer programs and exam sheets.
- The theoretical lectures will be given in English. Support will be given to the students concerning specific technical terms pertaining to fluid dynamics, including pronunciation and correct spelling.
- The presentation of practicals or daily exercises by the students will be either in Spanish or English depending on the students' preferences and their proficiency in those languages. The language to use will be chosen by the students on a case-by-case basis.

7. Metodología y volumen de trabajo del estudiante

Descripción

Credits: **6,0 ECTS**

Total hours: 150

Theoretical lectures: 26 classroom hours

Practical and exercise sessions: 30 classroom hours

Exam sessions: 4 classroom hours

Work at home by the students to process the theoretical lectures: 37 hours of independent work

Work at home by the students to prepare the practicals and exercise sessions: 38 hours of independent work

Exam preparation: 15 hours of independent work

Total of hours: 60 classroom hours plus 90 hours of independent work

The exercise and practical sessions will require the active participation of the students: the exercise solutions will be presented by the students themselves, followed by discussion with the lecturer and the other students. The solution of exercises and practicals constitute an essential part of the course. The practicals will involve the construction of small Python programs to solve comparatively simple numerical tasks, all with a view to allowing the students to explore on their own the physics of the topics presented in the theoretical lectures.

Concerning the foreseeable limitations to the actual presence of the students in the classroom in this academic year: if the number of students is not above the maximum admissible in the corresponding classroom, both the lectures and the exams will take place on-site. Otherwise, the lectures will be given in an asynchronous manner, using the online facilities for the lecture course. The on-site attendance of the students will take place by daily turns, with the students distributed in groups and each group having access to the classroom according to the official timetable established before the beginning of the course.

Actividades formativas en créditos ECTS, su metodología de enseñanza-aprendizaje y su relación con las competencias que debe adquirir el estudiante

Actividades formativas	Horas presenciales	Horas de trabajo autónomo	Total horas	Relación con competencias
Clases teóricas	26,00	0,00	26,0	[CE33], [CE32], [CE31], [CE30], [CE29], [CE28], [CE27], [CE26], [CE25], [CE24], [CE23], [CE20], [CE19], [CE18], [CE17], [CE16], [CE15], [CE14], [CE13], [CE12], [CE11], [CE7], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG8], [CG7], [CG6], [CG5], [CG4], [CG3], [CG1]

Clases prácticas (aula / sala de demostraciones / prácticas laboratorio)	15,00	0,00	15,0	[CE33], [CE32], [CE31], [CE30], [CE29], [CE28], [CE27], [CE26], [CE25], [CE24], [CE23], [CE20], [CE19], [CE18], [CE17], [CE16], [CE15], [CE14], [CE13], [CE12], [CE11], [CE7], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG8], [CG7], [CG6], [CG5], [CG4], [CG3], [CG1]
Realización de seminarios u otras actividades complementarias	15,00	0,00	15,0	[CE33], [CE32], [CE31], [CE30], [CE29], [CE28], [CE27], [CE26], [CE25], [CE24], [CE23], [CE20], [CE19], [CE18], [CE17], [CE16], [CE15], [CE14], [CE13], [CE12], [CE11], [CE7], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG8], [CG7], [CG6], [CG5], [CG4], [CG3], [CG1]

Realización de exámenes	4,00	0,00	4,0	[CE33], [CE32], [CE31], [CE30], [CE29], [CE28], [CE27], [CE26], [CE25], [CE24], [CE23], [CE20], [CE19], [CE18], [CE17], [CE16], [CE15], [CE14], [CE13], [CE12], [CE11], [CE7], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG8], [CG7], [CG6], [CG5], [CG4], [CG3], [CG1]
Estudio y trabajo autónomo en todas las actividades	0,00	90,00	90,0	[CE33], [CE32], [CE31], [CE30], [CE29], [CE28], [CE27], [CE26], [CE25], [CE24], [CE23], [CE20], [CE19], [CE18], [CE17], [CE16], [CE15], [CE14], [CE13], [CE12], [CE11], [CE7], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG8], [CG7], [CG6], [CG5], [CG4], [CG3], [CG1]
Total horas	60,00	90,00	150,00	
Total ECTS			6,00	

8. Bibliografía / Recursos

Bibliografía Básica

- Acheson, D.J. (1990): Elementary Fluid Dynamics. Oxford University Press.
- Batchelor, G.K. (1967): An Introduction to Fluid Dynamics
Cambridge University Press.
- Landau, L.D., Lifshitz, E.M. (1988): Fluid Mechanics, Vol 6, 2nd edition. Elsevier Science.
- Tritton D.J. (1988): Physical Fluid Dynamics

Oxford University Press.

Bibliografía Complementaria

- Clarke C.J. and Carswell R.F. (2007): Astrophysical Fluid Dynamics. Cambridge University Press
- Courant, R., Friedrichs, K. (1976): Supersonic Flow and Shock Waves. Springer-Verlag, New York.
- Laney, C.B. (1998): Computational Fluid Dynamics. Cambridge Univ Press
- Lighthill, J. (1980): Waves in Fluids. Cambridge University Press.
- Mihalas, D., Mihalas, B. (1999): Foundations of Radiation Hydrodynamics. Dover Books
- Shu, F. H. (1992): The Physics of Astrophysics, volume II: Gas Dynamics. University Science Books.

Otros Recursos

The practicals will consist in simple exercises that include Python programming and physical interpretation. They will not be computationally demanding, so as to allow the students to carry them out in standard laptops or desktops with the Python package installed. Typical examples of numerical techniques to use are: integration of ordinary differential equations, isoline and contour map representations in twodimensional maps and, for aerodynamics problems, use of complex variable techniques in numerical environments. In some cases the solution of partial differential equations in very simple contexts will be proposed.

9. Sistema de evaluación y calificación

Descripción

There are two possibilities for the evaluation of this lecture course: continuous evaluation and final exam. The student can opt for either of them, or for the combination of the two explained in the following.

(a) The continuous evaluation will be based on the marks obtained in the following activities, carried out along the course:

- tests for partial blocks of the course ("partial exams"). They will constitute 90% of the global mark (30% each exam). There will be three such exams along the course.
- Active participation in the classroom, exercise solving in joint sessions with the other students, positive attitude toward learning in this lecture course (10%)

(b) The final exam of the course will take place in the officially prescribed dates and will consist of a written test about the knowledge and skills acquired along the course. It will be based on theoretical questions and exercises similar to those solved along the course. The exam will not contain exercises that require the knowledge or use of the Python programming language. The exam will take place either in the classroom or online depending on the number of students and the maximum capacity of the assigned rooms.

(c) The students that have passed the continuous evaluation along the course need not go for the final exam if they so

choose. Those who have not passed, or have not opted for, the continuous evaluation, must pass the final exam to pass the course. Those students that have marks for both the continuous evaluation and the final exam will receive a global mark for the whole course following the formula specified in the General Memorandum of the Physics Degree, namely: calling 'c' the mark obtained in the continuous evaluation and 'z' that of the final exam, each of them in a scale between 0 and 10, the final mark will be calculated through the formula:

$$P = z + 0.4 c (1 - z / 10)$$

whenever $z > 10 / 3$. Otherwise, $P = z$. This combination of continuous evaluation and final exam will be applicable independently of the call in which the final exam is passed within the present academic year. For those students who have not gone for the continuous evaluation, the global mark of the course will be the one they have obtained in the final exam.

Estrategia Evaluativa

Tipo de prueba	Competencias	Criterios	Ponderación
Pruebas objetivas	[CE33], [CE30], [CE29], [CE28], [CE26], [CE24], [CE23], [CE19], [CE17], [CE14], [CE13], [CE11], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG6], [CG4], [CG3]	- Analytical and synthetic capabilities - Precision in the calculations - logical clarity and rigorous reasoning - writing skills, orthography, general presentation abilities	65,00 %
Informes memorias de prácticas	[CE33], [CE30], [CE29], [CE26], [CE25], [CE24], [CE23], [CE20], [CE19], [CE18], [CE17], [CE16], [CE15], [CE14], [CE13], [CE12], [CE11], [CE7], [CE6], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG8], [CG7], [CG6], [CG5], [CG4], [CG3], [CG1]	- Analytical and synthetic capabilities - Precision in the calculations - logical clarity and rigorous reasoning - writing skills, orthography, general presentation abilities - Level of discussion and interpretation of the results - Creativity	25,00 %

Escalas de actitudes	[CE32], [CE31], [CE30], [CE29], [CE28], [CE27], [CE26], [CE24], [CE23], [CE19], [CE17], [CE14], [CE11], [CE7], [CE5], [CE4], [CB5], [CB4], [CB3], [CB2], [CG7], [CG4]	Important criteria for this evaluation item are: the active participation of the student in the classroom, their presentation of exercises in the blackboard, their positive attitude toward learning the topic of the lecture course.	10,00 %
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10. Resultados de Aprendizaje

The objective of the course is that the students grasp the basic physical and mathematical principles that govern the behavior of fluids, that they develop the necessary skills to deal with them, and that they become acquainted with different aspects of their application to astrophysical systems. Some of the expected results obtained in the course are:

- In-depth training in basic physical concepts like the conservation laws for continua, the volume density and flux of extensive physical quantities, etc
- First opportunity to acquire experience in the combination (and conceptual separation) of the mechanical and thermodynamical aspects in the physical description of the gases.
- Training in the use of tensor quantities, which can also serve as preliminary training for the General Relativity lecture course.
- Learning of basic ideas about dimensions and dynamical similarity in physical systems
- Understanding of the relationship between the microscopic and macroscopic description of a continuous medium.
- Exposure to the concept of viscosity and acquisition of first ideas concerning turbulence.
- Through the study of wave propagation and instabilities using a classical small-perturbation approach, understanding of the linear behavior of intrinsically nonlinear systems.
- First meeting with physical situations containing sharp transitions (shock fronts) that naturally result from the physical evolution of the system.
- Access to the physics of the cosmos by way of gas dynamics, in particular concerning stellar structure and cosmic plasma physics. Specific applications envisaged are: solar and stellar winds, accretion disks, supernova remnants, internal gravity waves, astrophysical instabilities.

11. Cronograma / calendario de la asignatura

Descripción

The attached chronogram is only an approximate guide and can be modified depending on the needs of the students and the general progress of the course.

Primer cuatrimestre

Semana	Temas	Actividades de enseñanza aprendizaje	Horas de trabajo presencial	Horas de trabajo autónomo	Total
Semana 1:	1	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 2:	1 and 2	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 3:	2	Classroom work: 2 hr theory + 1 hr exercise solving. Additionally: independent work by the student.	3.00	4.00	7.00
Semana 4:	2	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 5:	3	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 6:	3 and 4	Classroom work: 2 hr theory + 1 hr exercise solving. Additionally: independent work by the student.	3.00	4.00	7.00
Semana 7:	4	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 8:	4 and 5	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 9:	5	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 10:	5	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	4.00	8.00
Semana 11:	6	Classroom work: 1 hr theory + 1 hr exercise solving. Additionally: independent work by the student.	2.00	4.00	6.00
Semana 12:	6	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	6.00	10.00

Semana 13:	7	Classroom work: 2 hr theory + 1 hr exercise solving. Additionally: independent work by the student.	3.00	6.00	9.00
Semana 14:	7	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	6.00	10.00
Semana 15:	1-7	Classroom work: 2 hr theory + 2 hr exercise solving. Additionally: independent work by the student.	4.00	6.00	10.00
Semana 16 a 18:	Evaluation	Independent work by the student in preparation of the exam. 5 hour classroom work to carry out the exam tests.	5.00	22.00	27.00
Total			60.00	90.00	150.00