Study Plan

School: Institute for Advanced Studies and Research
Degree: Doctorate
Course: Mechatronics Engineering and Energy (cód. 456)

Specialization Energy

1st Year - 1st Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
MAT8996D	Computational Mathematics and Optimization	Mathematics	6	Semester	156
INF8997D	Advanced Programmimg	Informatics	6	Semester	156
FIS8995D	Electromechanics of Continuous Media	Physics	6	Semester	156

Group of Options

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
FIS9007D	Complexflow Structures of Earth Fluids	Energy and Environment	3	Semester	78
FIS9008D	Fossil Fuels and Carbon Sequestration	Energy and Environment	6	Semester	156
FIS9009D	Atmospheric Modelling	Energy and Environment	3	Semester	78
FIS9010D	Resources, Energy and Environment	Energy and Environment	6	Semester	156
FIS9011D	Advanced Energy Conversion Systems	Energy and Environment	6	Semester	156
FIS9012D	Advanced Combustion Topics	Energy and Environment	6	Semester	156
FIS9013D	Advanced Computational Fluid Mechanics Topics	Energy and Environment	6	Semester	156
FIS9014D	Advanced Topics on Energy Transfer	Energy and Environment	6	Semester	156
FIS10557D	Advanced Optimization on Electric Energy Systems	Energy and Environment	6	Semester	156
FIS10558D	Optimization of Equipments and Thermal Systems	Energy and Environment	6	Semester	156
FIS10559D	Applied Optics to Solar Radiation Concentration: New Applications	Energy and Environment	6	Semester	156
FIS10560D	Thermal Conversion of Solar Radiation at Medium and High Temperatures: Technologies and Applications	Energy and Environment	6	Semester	156

*** TRANSLATE ME:Optativa livre ***

1st Year - 2nd Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

2nd Year - 3rd Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

2nd Year - 4th Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

3rd Year - 5th Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

3rd Year - 6th Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

4th Year - 7th Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

4th Year - 8th Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

Conditions for obtaining the Degree:

*** TRANSLATE ME: Para aprovação na componente curricular nesta especialização deste programa de doutoramento é necessário a aprovação (através de avaliação ou creditação) das seguintes unidades curriculares:{\}newline
{\}newline
1º Semestre: {\}newline
- 3 UC Obrigatórias num total de 18 ECTS {\}newline
- 2 UC Optativas num total de 12 ECTS do conjunto de optativas disponíveis no plano de estudos desta especialização.{\}newline
{\}newline
Para obtenção do grau, é necessário a aprovação na tese num total de 210 ECTS do 1º ao 4 ano ***

Specialization Mechatronic

1st Year - 1st Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
MAT8996D	Computational Mathematics and Optimization	Mathematics	6	Semester	156
INF8997D	Advanced Programmimg	Informatics	6	Semester	156
FIS8995D	Electromechanics of Continuous Media	Physics	6	Semester	156

1st Year - 1st Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Group of Options					

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
FIS8998D	MEMS Analysis and Modelling	*** TRANSLATE ME: Electrónica e Instrumentação/Projecto e Automação Industrial ***	6	Semester	156
FIS9006D	Reconfigurable Computing	*** TRANSLATE ME: Electrónica e Instrumentação ***	6	Semester	156
FIS8999D	Smart Structures and Materials	*** TRANSLATE ME: Projecto e Automação Industrial ***	6	Semester	156
FIS9000D	Computational Mechanics	*** TRANSLATE ME: Projecto e Automação Industrial ***	6	Semester	156
FIS9001D	Optimization of Structures and Mechanical Systems	*** TRANSLATE ME: Projecto e Automação Industrial ***	6	Semester	156
FIS9005D	Electronic Design Automation	*** TRANSLATE ME: Electrónica e Instrumentação ***	6	Semester	156
FIS9002D	Automatic Measurement Systems	*** TRANSLATE ME: Electrónica e Instrumentação ***	6	Semester	156
FIS9003D	Advanced Systems of Controle and Supervision	*** TRANSLATE ME: Electrónica e Instrumentação/Projecto e Automação Industrial ***	6	Semester	156
FIS9004D	Advanced Sytems Robotic	*** TRANSLATE ME: Electrónica e Instrumentação/Projecto e Automação Industrial ***	6	Semester	156
FIS10561D	Advanced Topics on Electronics and Energy	*** TRANSLATE ME: Electrónica e Instrumentação ***	6	Semester	156
*** TRANSLATE ME:Optativa livre ***					

1st Year - 2nd Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

2nd Year - 3rd Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

2nd Year - 4th Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

3rd Year - 5th Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

3rd Year - 6th Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

4th Year - 7th Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

4th Year - 8th Semester
Specialization Mechatronic

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

Conditions for obtaining the Degree:

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- 2 UC Optativas num total de 12 ECTS do conjunto de optativas disponíveis no plano de estudos desta especialização.{\}newline
{\}newline
Para obtenção do grau, é necessário a aprovação na tese num total de 210 ECTS do 1º ao 4 ano ***

Conditions for obtaining the Degree:

*** TRANSLATE ME: Área de Especialização em Energia:{\}newline

{\}newline

Para aprovação na componente curricular nesta especialização deste programa de doutoramento é necessário a aprovação (através de avaliação ou creditação) das seguintes unidades curriculares:{\}newline

{\}newline

1º Semestre: {\}newline

- 3 UC Obrigatórias num total de 18 ECTS {\}newline

- 2 UC Optativas num total de 12 ECTS do conjunto de optativas disponíveis no plano de estudos desta especialização.{\}newline

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Para obtenção do grau, é necessário a aprovação na tese num total de 210 ECTS do 1º ao 4 ano{\}newline

{\}newline

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Área de Especialização em Mecatrónica:{\}newline

{\}newline

Para aprovação na componente curricular nesta especialização deste programa de doutoramento é necessário a aprovação (através de avaliação ou creditação) das seguintes unidades curriculares:{\}newline

{\}newline

1º Semestre: {\}newline

- 3 UC Obrigatórias num total de 18 ECTS {\}newline

- 2 UC Optativas num total de 12 ECTS do conjunto de optativas disponíveis no plano de estudos desta especialização.{\}newline

{\}newline

Para obtenção do grau, é necessário a aprovação na tese num total de 210 ECTS do 1º ao 4 ano ***

Program Contents

Back

Computational Mathematics and Optimization (MAT8996D)

Floating point arithmetics: Representation of numbers in computational machines. Problem condition number.
Differentiation, integration and interpolation: Computation of derivatives of any order. Quadrature formulas, adaptive methods. Numerical errors. Lagrange, Hermite and Ck interpolation. Splines and NURBS. Interpolation of curves, surfaces and volumes.
Solution of linear and nonlinear equations systems: Direct and iterative methods for linear systems. Methods for sparse, dense and large dimension systems. Newton and quasi-Newton methods.
Differential equations: Functions approximations. The finite difference method. Methods for time integration. Optimization: Unconstrained optimization. Necessary optimum conditions. Methods for functions of several variables, with or without using derivatives. Constrained optimization. Optimality conditions. Interior point method. Multi-objective optimization. Global optimization. Genetic algorithms. Optimum control problems.

Back

Advanced Programmimg (INF8997D)

Programming languages: The programming languages paradigms, sequential, object oriented. Examples using (according the most recent standards) Fortran, C, C++, Matlab and Phyton.
Algorithms implementation: Data structure, problem subdivision, definition of classes and objects, definition of the computation sequence. Numerical libraries. Languages interoperability. Graphical interface and results visualization packages. Automatic code documentation.
Parallel computing: Motivation. Fundamental aspects of parallel processing architectures. Parallelization of algorithms. Tools for message passing between processors. Performance issues. Examples. GRID. Libraries for numerical parallel processing.

Back

Electromechanics of Continuous Media (FIS8995D)

The constitution of matter and the continuum hypothesis. Phenomena of piezoelectricity, electrostriction and magnetostriction, among others.
Mechanics of continuous media. Eulerian and Lagrangian descriptions, deformation measures and rates. Distributed forces and couples, measures of stress. Objectivity. Balance laws for the mass, momentum and energy in the integral and local form. Thermodynamics.
Electrodynamics: The notions of charge, current and electric and magnetic fields. Maxwell equations in the integral and differential form and the electroquasistatic (EQS) and magnetoquasistatic (MQS) approaches. Extension to the presence of matter, electrical and magnetic macroscopic forces applied over the matter. Electromagnetic radiation.
Constitutive models: Thermal, elastic, plastic, viscoelastic, fluid, electrical behaviour and its combinations.
Equations of the electromagnetic continuum. Specializations for some cases of solids and fluids.

Back

Complexflow Structures of Earth Fluids (FIS9007D)

-Flows between volume (surface) to point and point to volume (surface). Competing regimes. Fluid trees.
- Constructal theory. Flow optimization under local constraints. Structure of fluid trees.
-Scaling laws. Hierarchy of scales Fractal description. Fractals and dynamics.
Application: River basins; flow though porous media (sub-soil); convective boundary layer; convection at planetary scale.

Back

Fossil Fuels and Carbon Sequestration (FIS9008D)

Geological genesis and deposits of hydrocarbons and coals. Resource base and reserve categories. Conventional and non-conventional hydrocarbon reserves. Types of deposits and extraction technologies. Enhanced oil and gas recovery.
Production and consumption statistics of fossil fuels. Categories and timelines. Energy efficiency of primary energy extraction. Assessment of ultimate reserves. Depletion rates and the Hubbert curve.
Petrochemical technologies. Conversion of solid and of gaseous fuels into synthetic fuels and feed-stocks. CTL and GTL trends. Syncrude.
Carbon biogeochemical cycle basics. Fossil fuels' combustion emissions. CO2 capture methods in power stations. CO2 sequestration; geological and oceanic sequestration solutions and opportunities.

Back

Atmospheric Modelling (FIS9009D)

Scales of motions and types of atmospheric models: LES, mesoscale, weather forecast and general circulation models.
The governing equations. Coordinate systems and projections.
Numerical methods and computational concepts. Discretization of the dynamic equations and parameterization of subgrid-scale physical processes.
Atmosphere-surface interactions and Boundary Layer representations. turbulence
Radiative transfer schemes. Clouds and precipitation. Shallow and deep convection. Atmospheric chemistry and aerosols parameterizations.
Data assimilation and model initialization.
Performing numerical simulations with atmospheric models: case studies

Back

Resources, Energy and Environment (FIS9010D)

- The climate system and environmental fluxes. Solar energy and planetary mechanical energy (wind, wave and hydropower energies). Photosynthesis and biomass. Potentialities and limitations for renewable energy and matter flows use.
- Mineral resources in the crust and the ocean. Amounts and types of mineral sources. Prospecting and discovery; quantification and time evolution of resources availability. Mineral extraction and processing; environmental impacts. Nature as source and sink of all fluxes; fluxes of energy and matter in the geosphere. Life-cycle analysis of economic activities.

Back

Advanced Energy Conversion Systems (FIS9011D)

1. Thermoynamics and chemical kinetics in homogeneous and heterogeneous media.
2. Kinetics and transport phenomena in energy systems.
3. Direct and indirect energy conversion.
4. Energy conversion using renewable energy systems.
5. Optimal integration of heterogeneous energetic systems for hybrid utilization.
6. Energy vectors production (hydrogen, syngas, etc.)
6. Theoretical chemistry fundamentals associated to energy conversion on the micro and macroscopic level.
7. Examples of energetic systems, referring, fuel cells, PV, supercritical cycle, combined cycle and advances gas turbine cycles.
8. Examples of power plants from industrial scale to microgeneration.

Back

Advanced Combustion Topics (FIS9012D)

1. Revisions of the basic aspects of combustion. Conservation equations for reacting flows. Chemical kinetics.
2. Turbulent flames. Structure of turbulent premixed and non-premixed flames. Turbulent flame speed. Flame stabilization.
3. Burning of liquids. Droplet evaporation and burning. Atomization and sprays. Combustion of sprays.
4. Burning of solids. Phenomena involved in the burning of solids. Heterogeneous reactions. Burning of carbon. Pulverized particles combustion. Fixed bed combustion. Fluidized bed combustion.
5. Energetic valorisation of biomass. Biomass characterization. Pyrolysis. Gasification. Types of gasifiers.

Back

Advanced Computational Fluid Mechanics Topics (FIS9013D)

1. Conservation equations for reacting flows. Fundamentals of chemical kinetics. Passive scalars and mixture fractions. Reynolds and Favre decomposition. Conservation equations for turbulent flows.
2. Numerical implementation. Finite volume method. Discretization of the conservation equations. Solution methods for the disctrized equations. Numerical accuracy. In-house and commercial software.
3. Turbulence models.
4. Ratiative heat transfer equation in participating media. Radiative properties of gases and particles. Models for the calculation of radiative properties of gases and particles. Zone, Monte Carlo, discrete ordinates, discrete transfer and P1 methods. Numerical implementation of the discrete ordinates method.
5. Pollutants formation models. NO formation mechanisms. NO formation models. Soot formation mechanisms. Soot formation and oxidation models. Numerical implementation of the Zeldovich model.
6. Solution of reacting flows using a commercial code.

Back

Advanced Topics on Energy Transfer (FIS9014D)

1. Revision of the fundamentals of thermal radiation and radiation exchange.
2. Radiative transfer in participating media: radiation in vacuum; attenuation by absorption and scattering; augmentation by emissiona and scattering; the radiative transfer equation and solution mehods
3. Radiative properties of gases: Emissiona and Absorption probabilities; atomic and molecular spectra; spectral models (narrow/ wide bands); total emissivity and mean absorption coefficient.
4. Radiatiation on particulate media and Radiation on semitransparent media;
5. Solution methods for the RTE: exact solution for one-dimensional gray media; approximate solution methods for one-dimensional media; numerical methods: PN-Approximation, the method of discrete ordinates, the zonal method.
6. Radiation combined with conduction and convection: radiation and conduction; radiation and convection in boundary layers; radiation and free convection; radiation and combustion; interaction radiation/ turbulence.

Back

Advanced Optimization on Electric Energy Systems (FIS10557D)

1.Energy Planning (EP)
Scheduling of EP; Historical Perspective of PS; Structure of PS; Production System and Load Diagram; Supply-side and Demand-side Models
2. Optimization Methods (OM)
Dynamic Programming (DP); Lagrangian Relaxation (LR); Linear Programming; Nonlinear Programming; Mixed Integer Linear Programming (MILP)
3. Scheduling of Thermal Units
Problem formulation (PF); Restrictions on Thermal Units (TU) and Hydraulic Units; Suboptimization and Optimality Principle; DP and LR
4. Economic Dispatch (ED) of TU
Function of Cost (FC); Linearization Techniques of FC; Equality and Inequality constraints; PF of ED; Optimization: MILP; Losses
5.Optimal Power Flow (OPF)
Problem of ED in the PS; PF of OPF; Primal / Dual solution
6. Hydrothermal coordination (HTC)
PF; HTC Short Term; Reservoirs in Cascata; Lagrange function; Lagrange's dual problem; OM: LR
7.Price
EI of the Lagrange Dual Function; Marginal Price (M); Marginal Cost (MC); Shadow prices; Price Policies
8. Simulation and optimization

Back

Optimization of Equipments and Thermal Systems (FIS10558D)

1. Review of thermodynamics, fluid mechanics and heat transfer and its use for thermal systems modeling.
2. Thermal components modeling (compact heat exchangers and heat sinks, solar thermal collectors, solar thermal receivers in concentration systems, heat pumps and others). Governing equations and fluid flow and heat transfer modeling.
3. Simulation of thermal systems – global model development and simulation techniques through the solution of systems of non-linear equations. Applications.
4. Optimization of thermal systems:
(I) use of simulation models for efficiency optimization;
(II) entropy generation minimization;
(III) exergy analysis and irreversibility.
5. Optimization of fluid flow and internal geometric structure of compact heat sinks and heat exchangers. Convection in porous media.

Back

MEMS Analysis and Modelling (FIS8998D)

Introduction to MEMS: Examples of developed succeeded applications, actuators, sensors and offered possibilities.
Materials used in the applications: Possibilities offered by different materials, manufacturing related constraints. Material testing at this scale. Active materials, sensors and actuators.
Manufacturing processes: Chemical based processes. Mechanical based processes.
Modelling: Scale factor and the relevance of the associated phenomena. The contribution of gravity, electromagnetic, thermal and friction forces for the system behaviour. Governing equations of the structural system. Microfluidics and fluid structure interaction. Multiscale methods and particulate dynamics.
Analysis and design: The finite element method as an analysis tool. Application to the development of miniaturized machines, mechanisms, sensors and actuators.

Back

Reconfigurable Computing (FIS9006D)

1. Introduction to reconfigurable computing.
2. Reconfigurable hardware architectures: CPLDs e FPGAs.
3. Fine-grain and coarse-grain granularity.
4. Hardware description languages.
5. FPGA synthesis and mapping.
6. Fixed and reconfigurable processors.
7. Reconfigurable systems.
8. Static, dynamic and partial reconfiguration.
9. Hardware/software combined project.
10. New reconfigurable technologies.
11. Applications.

Back

Smart Structures and Materials (FIS8999D)

Application tailored materials. Anisotropy benefits. Classes of composite materials. Used materials and main manufacture processes. Constitutive laws, failure modes and criteria. Delamination, fracture and fatigue problems.
Composite materials modelling. Laminated plate and shell theories. Finite element models. Multiscale analysis.
Introduction to the smart material systems concept. Sensors and actuators. Ferroelectricity, piezoelectric, piezomagnetic, electrostrictive and magnetostrictive metallic, polymeric and ceramic materials. Main production processes. Constitutive laws. Shape memory alloys. Electrorheological and magnetorheological fluids. Passive and active damping capacity. Actuation force. Vibration absorbers. Optical fibers.
Smart structural components. Structure-actuator interaction. Current control systems. Active and passive vibration control in beams and plates.

Back

Computational Mechanics (FIS9000D)

Review of the basic equations of continuous media and energy principles in structural mechanics. Numerical solutions by finite differences, FEM and boundary elements.
Introduction to the usage of commercial codes, ANSYS, ABAQUS and integrated systems. CAE, CAD/CAM and CIM systems.
The Finite Element Method. Discrete approach and the computational implementation. Continuous approach. Formulation of beam, plate, shell and solid elements. Dynamic analysis, linear buckling. Comparison with commercial codes.
Introduction to nonlinear analysis, plasticity and large deformation analysis.
Element formulation for the solution of coupled problems (electrical, magnetic, thermal, mechanical , etc.) including active materials (piezoelectrics, magnetostrictives, electrostrictives, etc.). Finite element formulations for fluid flow.
Introduction to multiple scales analysis. Micromechanics and homogenization. Theorems and bounds on change and equivalence of scales.

Back

Optimization of Structures and Mechanical Systems (FIS9001D)

Objective functions on structures. Optimization algorithms. Local and global optimum. Sensitivity Analysis: design variables. Sensibilities by finite difference. Analytical sensitivities. Automatic differentiation. Classic algorithms, evolutionary and genetic. Use of Matlab and Ansys programs in analysis and optimization of structures, plates, shells and composites structures.
Global systems of equations to analyze kinematic mechanism and its numeric solution. The resolution using the Newton-Raphson iteration method, and the modularity of the construction of the jacobiana array. Analysis of models contained in commercial codes and its applicability.
Beam and plate finite elements. Formulation of flexible bodies. Methods of substructures. Linearization complex systems. Control of mechanical systems and structures as application examples. Biomechanics of movement as a test case. Contact/impact of mechanical systems

Back

Electronic Design Automation (FIS9005D)

1. Introduction. "EDA" Concept.
2. Design environments.
3. Symbolic project.
4. High-level project.
5. Modelling.
6. Testing.
7. Implementation.

Back

Automatic Measurement Systems (FIS9002D)

AMS: Automatic measure. Definition and purpose of a AMS.
Revisions of metrology: measurement, Accuracy, accuracy class, uncertainties, law of propagation of uncertainty, probabilistic distribution laws.
Methods of adjustment and approximations of functions: Criteria of least squares, Chebyshev criterion.
Revisions of digital instrumentation.
Communication interfaces: GPIB, RS232, USB 2.0.
IEEE 488.2: Communication protocol (handshaking) Physical characterization.
Project SAM.
Virtual instrumentation.
Laboratory applications: Draft a SAM to:
- Measurement of impedances.
- Determination of the transfer function of dynamic systems.
- Determination of frequency response of filters.
- Measurement of signal noise.
- Characterization of A/D converters by static and dynamic methods.
- Measurement and characterization in the frequency domain of audible noise.
- Measurement of mechanical deformations.
- Measurement of meteorological and environmental parameters.

Back

Advanced Systems of Controle and Supervision (FIS9003D)

1) Review of Control Systems: State-Space formulation, Regulators and State Observers.
2) Optimal Control Systems: Performance indexes; optimization problems, Optimal control systems based on quadratic performance indexes; Time optimal control systems.
3) Model Reference Control Systems: Adaptive controllers and Predictive Controllers.
4) Analog/ Digital Controllers.
5) Review of sequential systems based on programmable automation - PLCs.
6) Local Control and Remote Control. The communication in distributed systems. Industrial communication networks (Ethenet and ProfiBus). Cooperation among GRAFCETmultiple processes. The management of Master/Slave control chains.
7) SCADA Systems. Implementation examples with commercial applications: Axeda Supervisor and Siemens WinCC.
8) Design and implementation of a SCADA application using OPC protocol to communicate with other softwares: Matlab, LabView, etc.
9) Development of specific drivers using advanced control algorithms.

Back

Advanced Sytems Robotic (FIS9004D)

1) Review of Robotic Systems: Mathematical models of the robotic typical components; kinematic chains (direct and inverse kinematics); robotic dynamics.
2) Robotic Controllers: Independent-joint controller, resolved motion controller (hand coordinates). Linearized feedback controller, robust controller and adaptive controller.
3) Trajectory planning and maximization of functionals.
4) Practical aspects on the implementation of robotic position-controllers (Laboratory application with step-motors, encoders and PLC controller).
5) The automatic vision and its application to Robotics. Artificial vision equipment. Mathematical operators for image filtering and signal processing.
6) Practical aspects on the implementation of vision systems for robotics (laboratory applications based on Siemens VisionSensor VS710 e VS725)