Study Plan

School: Institute for Research and Advanced Training
Degree: Doctorate
Course: Mechatronics Engineering and Energy (cód. 720)

Specialization Mechatronics

1st Year - 1st Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
MAT13278D	Computational Mathematics and Optimization	Mathematics	6	Semester	156
INF13279D	Advanced Programming	Informatics	6	Semester	156
FIS13280D	Electro-mechanics of continuous media	Physics	6	Semester	156

Options

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13155D	Computational Mechanics	Mechanical Engineering	6	Semester	156
EME13156D	Smart Materials and Structures	Mechatronic Engineering	6	Semester	156
EME13157D	Optimization of Structures and Mechanical Systems	Mechanical Engineering	6	Semester	156
EME13159D	Electronic Design Automation	Electrotechnical Engineering	6	Semester	156
EME13160D	Automatic Measurement Systems	Electrotechnical Engineering	6	Semester	156
EME13161D	Advanced Control and Supervisory Systems	Mechatronic Engineering	6	Semester	156

1st Year - 2nd Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13281D	Development of Research Plan for Thesis - Mechatronics	Electrotechnical Engineering Mechanical Engineering Mechatronic Engineering	30	Semester	780

2nd Year - 3rd Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13297D	Thesis Monitoring I - Mechatronics	Electrotechnical Engineering Mechanical Engineering Mechatronic Engineering	3	Year	78
Thesis					

2nd Year - 4th Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

3rd Year - 5th Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13308D	Thesis Monitoring II - Mechatronics	Electrotechnical Engineering Mechanical Engineering Mechatronic Engineering	3	Year	78
Thesis					

3rd Year - 6th Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

4th Year - 7th Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13309D	Thesis Monitoring III - Mechatronics	Electrotechnical Engineering Mechanical Engineering Mechatronic Engineering	3	Year	78
Thesis					

4th Year - 8th Semester
Specialization Mechatronics

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

Specialization Energy

1st Year - 1st Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
MAT13278D	Computational Mathematics and Optimization	Mathematics	6	Semester	156
INF13279D	Advanced Programming	Informatics	6	Semester	156
FIS13280D	Electro-mechanics of continuous media	Physics	6	Semester	156

1st Year - 1st Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Options					

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13162D	Advanced Topics in Heat Transfer	Mechanical Engineering	6	Semester	156
EME13166D	Advanced Topics in Computational Fluid Dynamics	Mechanical Engineering	6	Semester	156
EME13171D	Thermal Conversion of Solar Radiation in the medium and high Temperature range: Technologies and Applications	Renewable Energy Engineering	6	Semester	156
EME13172D	Advanced Optimization in Power Systems	Electrotechnical Engineering	6	Semester	156
EME13173D	Optimization of Thermal Systems	Mechanical Engineering	6	Semester	156
EME13174D	Atmospheric Modeling	Mechanical Engineering	6	Semester	156

1st Year - 2nd Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13282D	Development of Research Plan for Thesis - Energy	Renewable Energy Engineering Electrotechnical Engineering Mechanical Engineering	30	Semester	780

2nd Year - 3rd Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
EME13298D	Thesis Monitoring I - Energy	Renewable Energy Engineering Electrotechnical Engineering Mechanical Engineering	3	Year	78
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
EME13306D	Thesis Monitoring II - Energy	Renewable Energy Engineering Electrotechnical Engineering Mechanical Engineering	3	Year	78
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
EME13307D	Thesis Monitoring III - Energy	Renewable Energy Engineering Electrotechnical Engineering Mechanical Engineering	3	Year	78
Thesis					

4th Year - 8th Semester
Specialization Energy

Component code	Name	Scientific Area Field	ECTS	Duration	Hours
Thesis					

Conditions for obtaining the Degree:

*** TRANSLATE ME:

Área de Especialização em Mecatrónica ou Energia:{\}newline

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

1º Ano

1º Semestre:

- 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 da respetiva especialização.

2º Semestre:

-1 UC Obrigatórias num total de 30 ECTS

Para obtenção do grau necessita obter ainda aprovção a:

2º Ano

3º Semestre:

-1 UC Obrigatórias num total de 3 ECTS

3º Ano

5ºSemestre:

-1 UC Obrigatórias num total de 3 ECTS

4º Ano

7º Semestre

-1 UC Obrigatórias num total de 3 ECTS

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e aprovação nas provas públicas de defesa da Tese com inscrição na mesma a partir do 2.º ano

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Program Contents

Back

Computational Mathematics and Optimization (MAT13278D)

-Floating point arithmetics: Binary representation and operations. Absolute and relative errors. Problem condition number.
-Differentiation, integration and interpolation: Comput. derivatives of any order. Quadrature formulas, adaptive meth. Numerical errors. Lagrange, Hermite and Ck interpolation. Splines and NURBS. Interpol. curves, surfaces and volumes. Interpol. errors.
-Sol. Lin. and nonlinear eq. Syst.: Direct and iterative meth. for linear systems. Meth. for sparse, dense and large dim. syst. Newton and quasi-Newton meth. for nonlinear systems.
-Diff. equations: Funct. approximations. Finite diff. meth. Meth. for time integration (Ruge-Kutta, multistep, Newmark...). Finite element meth.
-Optimization: Unconstrained optim. Necessary optimum cond. Meth. for 1-variable funct. Meth for n-variable funct., with or without using derivatives. Constrained optim. Optimality cond. Interior point meth. Multi-objective optim. Global optim. Genetic algorith. Optimum control problems.

Back

Advanced Programming (INF13279D)

- Programming languages: The programming languages paradigms, sequential, object oriented. Examples using (according the most recent standards) Fortran, C, Java, 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

Electro-mechanics of continuous media (FIS13280D)

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) approximations. 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

Computational Mechanics (EME13155D)

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

Smart Materials and Structures (EME13156D)

1. Smart materials and structures. Examples of application in several domains. Piezoelectrics, SMA (shape memory alloys), electroactive polymers, electro-rheologic and magneto-rheologic fluids, biomimetics.
2. Revisions of continuum mechanics and constitutive behaviour.
3. Electromagnetic active materials. Ferroelectricity, piezoelectricity, electrostriction, magnetostriction, electro-rheology. Constitutive laws.
4. Shape memory alloys. Constitutive law.
5. Application tailored materials. Composite materials. Anisotropy benefits.
6. Finite element models and multiscale analysis of active composites.
7. Design of smart structural components and mechanisms. Active and passive control. Failure modes and criteria.
8. Introduction to manufacturing.

Back

Optimization of Structures and Mechanical Systems (EME13157D)

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 (EME13159D)

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

Back

Automatic Measurement Systems (EME13160D)

Automatic measurement System (AMS): Definition and purposes.
Metrology revisions: Measurement, Accuracy, accuracy class, uncertainties, law of propagation of uncertainty, probabilistic distribution laws.
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.
SAM Design.
Virtual instrumentation.
Laboratory applications: Design a SAM to:
- Measurement of impedances.
- Determination of the TF of a 2nd order dynamic system.
- Determination of frequency response of a filter.
- Measurement of noise from a function generator.
- Characterization of A/D converters for static and dynamic methods.
- Measurement and characterization of audible noise in frequency domain.
- Measurement of deformations in mechanical structures.
- Measurement of meteorological and environmental parameters.

Back

Advanced Control and Supervisory Systems (EME13161D)

PART I:
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: Introduction to adaptive controllers. Predictive Controllers.
4) Digital Systems Analysis: digital implementation of analogue controllers, digital controllers.

PART II:
1) Review of project and implementation of sequential systems based on PLCs (Siemens S7-300).
2) local Control and Remote Control. Industrial communication networks (Ethenet and ProfiBus).
3) Cooperation among GRAFCETmultiple processes. The management of Master/Slave control chains.
4) SCADA Systems (Siemens WinCC).
5) OPC communication: SCADA - Matlab, LabView, etc.

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Development of Research Plan for Thesis - Mechatronics (EME13281D)

N.A. - Dependent on Thesis subject.

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Thesis Monitoring I - Mechatronics (EME13297D)

N.A. - Dependent on Thesis subject.

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Thesis Monitoring II - Mechatronics (EME13308D)

N.A. - Dependent on Thesis subject.

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Thesis Monitoring III - Mechatronics (EME13309D)

N.A. - Dependent on Thesis subject.

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Advanced Topics in Heat Transfer (EME13162D)

1.Revisions radiation and heat transfer (solid surf)

2.Eq. of radiative transfer in participating media: rad. in vacuum; attenuation by absorption and scattering; augmentation by emission and scattering; radiative transfer eq. and solution meth.

3.Radiative prop. gases: Emission and Absorption; atomic and molecular spectra; spectral, narrow and wide band models; total emissivity and mean absorption coef.

4.Radiative prop. of particulate media: absorption and scattering from sphere; radiative prop particle cloud; Ryleigh and Rayleigh-Gans scattering; radiative prop. large spheres; approx. scattering phase functions.

5.Radiative prop of semitransparent media: absorption by semitransparent solids and liquids;

6.Solutions for the RTE: exact sol. for one-dimensional gray media; approx. Sol. meth. for one-dimensional media; numerical meth.s: PN-Approx., meth. of discrete ordinates, the zonal meth.

7.Combined Radiation (conduction; convection; combustion). Interaction radiation/turbulence.

Back

Advanced Topics in Computational Fluid Dynamics (EME13166D)

1. Conservation eq. reacting flows. Chemical kinetics. Passive scalars and mixture fractions. Reynolds and Favre decomposition. Conservation eq. turbulent flows.

2. Numerical implement. Finite volume meth. Grid selection. Discretization conservation eqs. Solution meth. disctrized equations. Solution algorith. Numerical accuracy. In-house and commercial software.

3. Turbulence models. Zero equation models. 2-equation models: k-e and variants. Reynolds Stress Models. Large Eddy Simulation. Direct Numerical Simul. Numerical implement of k-e.

4. Radiative heat transfer eq. participating media. Models for radiative prop. of gases and particles. Zone, Monte Carlo, discrete ordinates, discrete transfer and P1 methods. Numerical implement. discrete ordinates method.

5. Formation models and mechanisms:Pollutants; NO; Soot. Numerical implement. Zeldovich model.

6. Solution of reacting flows using a commercial code.

Back

Thermal Conversion of Solar Radiation in the medium and high Temperature range: Technologies and Applications (EME13171D)

1 – The impact of concentration ratio in the temperature of solar radiation thermal conversion

2 – Line-focus concentrating systems: definition and design parameters

3 – Point-focus concentrating systems: definition and design parameters

4 – Optical assessment of concentrating systems: optical effects; incidence angle modifier; optical efficiency. Experimental and ray-trace based assessment.

5 – Thermal assessment of concentrating systems: evacuated and non-evacuated systems. Thermal performance assessment methodologies.

6 – Solar field models for different concentrating technologies

7 – Medium temperature thermal applications: characterization and definition of modeling parameters

8 - High temperature thermal applications: characterization and definition of modeling parameters

9 – System modelling for diferent applications: definition of components and system; operation modes; assessment parameters; calculation algorithm.

Back

Advanced Optimization in Power Systems (EME13172D)

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 Prog (DP); Lagrangian Relaxation (LR); Linear Prog; Nonlinear Prog; Mixed Integer Linear Prog (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 in Transmission

5.Optimal Power Flow (OPF)

Problem of ED in the PS; PF of OPF; Solution via Primal / Dual method

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

8.Simulation of Economical Optimization

Back

Optimization of Thermal Systems (EME13173D)

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

Atmospheric Modeling (EME13174D)

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.

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Development of Research Plan for Thesis - Energy (EME13282D)

N.A. - Dependent on Thesis subject.

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Thesis Monitoring I - Energy (EME13298D)
N.A. - Dependent on Thesis subject.

Back
Thesis Monitoring II - Energy (EME13306D)
N.A. - Dependent on Thesis subject.

Back
Thesis Monitoring III - Energy (EME13307D)
N.A. - Dependent on Thesis subject.