Education and Culture DG
Lifelong Learning Programme

ECMI

ECMI Model Master in Industrial Mathematics

with branches

Techno-Mathematics
Econo-Mathematics

ECMIMIM project

Project No. 134026-LLP-1-2007-1-ES-ERASMUS-ECDSP

Partners:

Universidad Carlos III Madrid

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Lunds Universitet

Technische Universität Dresden

École Nationale Supérieure des Mines de Paris

Tartu Ülikool

Oxford University

Autònoma Universitat de Barcelona

Model Master in Industrial Mathematics

Techno-Mathematics

The aim of the master programme in Industrial Mathematics is to develop the student's mathematical and computational skills to solve industrial problems and development tasks in innovative ways. Fundamental capabilities to be trained are:

- modelling and analytical skills,
- knowledge of numerical methods,
- skills in programming and simulation,
- experience with mathematical models in industry and economy,
- ability to handle huge amounts of data by integrating mathematical, numerical and statistical methods,
- team working, cooperation, communication with and presentations for mathematicians and engineers.

The master programme is international. The education is given in English.

The duration of the master programme is two years (120 ECTS). There are three course blocks (A, B and C) which are related to both the requirements for admission to the master study and compulsory courses of the master programme.

Requirements for admission

The following is required for admission:

- 180 ECTS of undergraduate study at university level (bachelor degree),
- Prerequisite courses covering the topics in course block A,
- Prerequisite courses covering topics of an amount of at least ½ of the total ECTS in block B i.e. at least 12 ECTS,
- Since the education is given in English, good communication skills in English are required both orally and in writing.

Requirements for certificate and compulsory courses

The following is required in the master study to receive the certificate:

- At least 120 ECTS in total, corresponding to two years study,
- At least one semester at one of the other universities of ECMI,
- Courses covering the remaining topics in block B,

- At least 60 ECTS of elective courses in course block C. Among these courses there should be mathematical courses (mathematics, mathematical statistics and numerical analysis) summing up to at least 42 ECTS and courses in a minor field of study related to mathematics of at least 12 ECTS,
- Modelling activities of at least 9 ECTS,
- A master thesis of 30 ECTS,
- Courses up to 120 ECTS (either from block C or e.g. economy, management, law).

Study blocks for the Techno-Mathematics Master

- **Block A:** Prerequisites (for admission to the Master programme)

Required topics

Basic knowledge in calculus	18 ECTS
Linear Algebra	6 ECTS
Some basics in numerical analysis	6 ECTS
Programming skills	6 ECTS
Basic knowledge in physics or mechanics	6 ECTS
Basics in statistics	6 ECTS
Total amount of courses	48 ECTS

- **Block B:** At least ½ of the listed topics are required for admission.
  The remaining topics are required during the Master study.

Required Topics:

Transforms, linear systems, basics in ODE	6 ECTS
Basics in PDE	6 ECTS
Numerics for differential equations	6 ECTS
Minor field of study related to mathematics	6 ECTS
Total amount of courses	at least 24 ECTS

- **Block C**: Elective courses in the field of industrial mathematics.
  Every student can choose among offered specialization courses at her/his home university or at an ECMI partner university.

Requirements:

Total amount of courses in block C	at least 60 ECTS
among these courses:	
Mathematical courses	at least 42 ECTS
Courses in a minor field of study related to mathematics	at least 12 ECTS

Modelling activities

International ECMI modelling week	3 ECTS
Further modelling activities (European Summer School, project, study groups, internships etc.)	6 ECTS

Master thesis

The thesis should be related to a real industrial problem. It could preferably be carried out in an interdisciplinary environment involving participants from industry. 30 ECTS

Details on the topics in block B for the Techno-Math. Master

Transforms, linear systems, basics in ODE: (examples of topics)

- Fourier series, Fourier and Laplace transforms
- Systems of linear differential equations (state space theory, diagonalization, stability)
- Quadratic forms
- Input-output relations (transfer function, impulse response)

Basics in PDE: (examples of topics)

- First order PDE
- Linear second order PDE
- Series expansions
- Fourier's method
- Green function
- Wave propagation
- Functions spaces and norms
- Distributions

Numerics for differential equations: (examples of topics)

- Methods for time integration
- Finite difference methods
- Explicit and implicit Runge-Kutta
- Multistep methods
- Error analysis, stability and convergence

Examples for courses in block C for the Techno-Math. Master

at University Carlos III Madrid

Singular Perturbations	AMS 32D15, 35B25, 76M45
Computational Fluid Dynamics	AMS 76M10,12,15,20,22,23, 25
Combustion	AMS 80A25, PACS 47.70.Pq, 82.33.Vx
Electronic Transport in Micro and Nanostructures	PACS 73.63.-b, 72.10.-d,72.20.Ht
Inverse problems and Imaging	AMS 92C55, PACS 87.57.-s 87.85.Pq

at Lappeenranta University of Technology

Design of Experiments (4 ects)	62Kxx
Simulation (4 ects)	68U20, 81T80
Statistical analysis in modelling (5 ects)	62F15, 62F25
Evolutionary computation (5 ects)	68W20,90C15, 90C59
Fuzzy data analysis (5 ects)	90C70, 62H30

Alternative titles

Applied functional analysis (5 ects)
Stochastic theory and models (5 ects)
Numerical Methods II (3 ects)
Statistics II (3 ects)
Nonlinear Optimization (4 ects)
Case Study Seminar (5 ects)

at Lund University

Image Analysis	AMS 62M40, 65D18
Monte Carlo and Empirical Methods for Stochastic Inference	AMS 65C05, 80M31
Electromagnetic Wave Propagation	AMS 78-XX, 35Q6
Mechanical Wave Propagation	AMS 74Jxx
Multivariable Control	AMS 93-XX, 34Hxx

at the Technische Universität Dresden

FEM - Theory, Implementation, and Applications
Phase Field Modelling
Discrete Optimization
Optimal Control of elliptic and parabolic PDE systems
Dynamical Systems
Kinematical Geometry
Simulation of Stochastic Processes

Minor field of study related to mathematics

E.g. courses in one of the following fields:

- advanced programming
- physics
- mechanics
- electrical engineering
- signal processing
- image processing
- automatic control
- biotechnology

Econo-Mathematics

The aim of the master programme in Industrial Mathematics is to develop the student's mathematical and computational skills to solve problems in industry and business and other research and development tasks. Fundamental capabilities to be trained are:

- modelling and analytical skills,
- knowledge of numerical methods,
- skills in programming and simulation,
- experience with mathematical models in industry and economy,ability to handle huge amounts of data by integrating mathematical, numerical and statistical methods.
- team working, cooperation, communication with and presentations for mathematicians and engineers.

The master programme is international. The education is given in English.

The duration of the master programme is two years (120 ECTS). There are three course blocks (A, B and C) which are related to both the requirements for admission to the master study and compulsory courses of the master programme.

Requirements for admission

The following is required for admission:

- 180 ECTS of undergraduate study at university level (bachelor degree)
- Prerequisite courses covering the topics in course block A
- Prerequisite courses covering topics of an amount of at least 12 ECTS of the total ECTS in block B i.e. at least 2 out of 6 topics
- Since the education is given in English, good communication skills in English are required both orally and in writing.

Requirements for certificate and compulsory courses

The following is required in the master study to receive the certificate:

- At least 120 ECTS in total, corresponding to two years study
- At least one semester at one of the other universities of ECMI
- Courses covering the remaining topics in block B
- At least 48 ECTS of elective courses in course block C. Among these courses there should be mathematical courses (mathematics, mathematical statistics and numerical analysis) summing up to at least 36 ECTS and courses in a minor field of study related to mathematics of at least 6 ECTS
- Modelling activities of at least 9 ECTS
- A master thesis of 30 ECTS

- Courses up to 120 ECTS (either from block C or e.g. engineering, management, law)

Study blocks for the Econo-Mathematics Master

- **Block A:** Prerequisites (for admission to the Master programme)

Required topics

Basic knowledge in calculus	18 ECTS
Linear Algebra	6 ECTS
Some basics in numerical analysis	6 ECTS
Programming skills	6 ECTS
Basics in statistics	6 ECTS
Total amount of courses	42 ECTS

- **Block B:** At least 2 out of 6 of the listed topics are required for admission. The remaining topics are required during the Master study.

Required topics:

Transforms, linear systems, basics in ODE	6 ECTS
Basics and numerics in PDE	6 ECTS
Stochastic processes	6 ECTS
Optimization	6 ECTS
Finances and Economics	6 ECTS
Quantitative Finances and Economics	6 ECTS
Total amount of courses	at least 36 ECTS

- **Block C:** Elective courses in the field of industrial econo-mathematics. Every student can choose among offered specialization courses at her/his home university or at an ECMI partner university.

Requirements:

Total amount of courses	at least 48 ECTS
among these courses:	
Mathematical courses	at least 36 ECTS
Quantitative Finances and Economics	at least 6 ECTS

Modelling activities

International ECMI modelling week	3 ECTS

Further modelling activities (European Summer School, project, study groups, internships etc.)	6 ECTS

Master thesis The thesis should be related to a real industrial problem. It could preferably be carried out in an interdisciplinary environment involving participants from industry. 30 ECTS

Details on the topics in Block B for the Econo-Mathematics Master

Transforms, linear systems, basics in ODE: (examples of topics)

- Fourier series, Fourier and Laplace transforms
- Systems of linear differential equations (state space theory, diagonalization, stability)
- Quadratic forms
- Input-output relations (transfer function, impulse response)

Basics and numerics in PDE: (examples of topics)

- First order PDE
- Linear second order PDE
- Series expansions
- Fourier's method
- Wave propagation
- Functions spaces and norms
- Distributions
- Methods for time integration
- Finite difference methods
- Explicit and implicit Runge-Kutta

Stochastic processes: (examples of topics)

- Models for stochastic dependence.
- Concepts of description of stationary stochastic processes in the time domain: expectation, covariance, and cross-covariance functions.
- Concepts of description of stationary stochastic processes in the frequency domain: effect spectrum, cross spectrum.
- Special processes: Gaussian process, Wiener process, white noise, Gaussian fields in time and space.
- Stochastic processes in linear filters: relationships between in- and out-signals, auto regression and moving average (AR, MA, ARMA), derivation and integration of stochastic processes.
- The basics in statistical signal processing: estimation of expectations, covariance function, and spectrum.
- Application of linear filters: frequency analysis and optimal filters.

Optimization: (examples of topics)

- Quadratic forms and matrix factorisation.
- Convexity.
- The theory of optimisation with and without constraints: Lagrange functions, Kuhn-Tucker theory, Duality.
- Methods of optimisation without constraints: line search, steepest descent, Newton methods, conjugate directions, non-linear least squares optimisation.

- Methods of optimisation with constraints: linear optimisation, the simplex method, quadratic programming, penalty and barrier methods.

Finances and Economics: (examples of topics, microeconomic theory)

- The theory of supply, demand and equilbrium on a market
- Consumer theory, i.e. the theory of the economic behaviour and decision-making of individuals.
- The theory of production and deals with the actions of a firm under various market structures (perfect competition, monopoly, oligopoly and monopolistic competition).
- Market failure externalities and public goods. Here, it is analysed how society deals with the production and distribution of goods where the market cannot achieve the optimal solution on its own.

Quantitative Finances and Economics: (examples of topics, microeconomic theory)

- The theory of individual choice; choice under uncertainty is treated separately.
- Application on financial and insurance problems.
- The dual approach to production theory is defined and applied to efficiency analysis of economic units.
- Game theoretic solution methods are defined and used to analyse firms' strategic quantity and price setting problems on markets with a small number of agents.
- Introduction to financial economics; among other things the theory of portfolio choice and equilibrium pricing of financial assets are discussed along with arbitrage free pricing of derivatives.

Examples for courses in block C for the Econo-Math. Master

at Lund University

Non-Linear Time Series Analysis	AMS 37M10, 91B84
Financial Statistics	AMS 91B84
Predictive Control	AMS 93-XX
Market-driven Systems	AMS 93-XX, 34Hxx
Microeconomics – Theory for Individual Choice and Game Theory	AMS 91-XX

at the Autonomous University of Barcelona

For Stochastic processes:	AMS 60G15, 60G44,60G46, 60J10, 60J60, 62M10
for economics: Micro economics and Macroeconomics	91B16, 91B24,91B38, 91B42, 91B50, 91B64
For quantitative finances and economics: Finance and econometrics	91B28, 91B30, 91B70, 62M10, 91B82, 91B84