

ECMI Model Master in Industrial Mathematics

with branches

**Techno-Mathematics
Econo-Mathematics**

ECMIMIM project

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Universidad Carlos III Madrid

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Universita' degli Studi di Milano

Lunds Universitet

Technische Universität Dresden

École Nationale Supérieure des Mines de Paris

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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 to the master programme

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 $\frac{1}{2}$ 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 the master degree

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

- At least 120 ECTS in total, corresponding to two years study,
- Courses covering the remaining topics in block B (see requirements for admission),

- At least 60 ECTS of elective courses in course block C. Among these courses there are required mathematical courses (mathematics, mathematical statistics and numerical analysis) summing up to at least 42 ECTS as well as 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,
- Further Courses up to 120 ECTS in total (e.g. from block C or from economy, management, law).

Additional requirements for the ECMI Certificate

To receive the ECMI Certificate additionally to the above requirements for the master degree in industrial mathematics the following is required:

- At least one semester of the study or the final master thesis project at one of the other universities of ECMI,
- Practical training in mathematical modelling, organized in a regular modelling seminar, Workload: 6 – 15 ECTS,
- Participation in the International ECMI Modelling Week (3 ECTS),
- Mathematical courses in
 - Scientific Computing
 - Optimization
 - Mathematical Statistics

Each student's qualification is finally assessed by the ECMI Educational Committee and is based on two review reports of the thesis by ECMI reviewers.

The application of a student for the ECMI certificate is usually organized by the ECMI responsible at the student's home university. It includes the thesis in english language and a full transcript of studies and modelling activities relevant for the ECMI programme.

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 $\frac{1}{2}$ 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, among these courses:	at least 60 ECTS
Mathematical courses	at least 42 ECTS
Courses in a minor field of study related to mathematics	at least 12 ECTS

- **Modelling activities**

Modelling activities (e.g. modelling seminar, summer school, study groups, industrial project, internships etc.)	at least 9 ECTS
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- **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

Total ECTS for Master degree:

$$12 \cdot x \text{ (Block B)} + 60 \text{ (Block C)} + 9 \text{ (Modelling)} + 30 \text{ (Thesis)} + 9 \cdot x \text{ (free)} = 120$$

$$(0 \leq x \leq 12)$$

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 Technische Universität Dresden

FEM - Theory, Implementation, and Applications	AMS 35-XX, 35Qxx
Phase Field Modelling	AMS 35Qxx, 35Q30
Advanced Programming	AMS 35Qxx
Dynamical Systems	AMS 37-XX,37Cxx,37Gxx,37N25, 37N10
Optimal Control of PDE	AMS 49J20

at Universita' degli Studi di Milano

Biomathematics 1 (6 ECTS)	AMS 92Dxx
Mathematical Finance 1 (6 ECTS)	AMS 91B28, 91B70
Mathematical Finance 2 (6 ECTS)	AMS 91B70, 60Hxx
Numerical Methods for PDE's III (9 ECTS)	AMS 65Mxx, 65Nxx
Stochastic Calculus and Applications (9 ECTS)	AMS 60Gxx, 60Hxx, 60Kxx

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

Model Master in Industrial Mathematics

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 the master degree

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

- At least 120 ECTS in total, corresponding to two years study,
- 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).

Additional requirements for the ECMI certificate

To receive the ECMI certificate additionally to the above requirements for the master degree in industrial mathematics the following is required:

- At least one semester of the study or the final master thesis project at one of the other universities of ECMI,
- Practical training in mathematical modelling, organized in a regular modelling seminar, Workload: 6 – 15 ECTS,
- Participation in the International ECMI Modelling Week (3 ECTS),
- Mathematical courses in
 - Computational Methods
 - Discrete Mathematics

Each student's qualifications are finally assessed by the ECMI Educational Committee based on two review reports of the thesis by ECMI reviewers.

The application of a student for the ECMI certificate is usually organized by the ECMI responsible at the student's home university. It includes the thesis in english language and a full transcript of studies and modelling activities relevant for the ECMI programme.

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, among these courses:	at least 48 ECTS
Mathematical courses	at least 36 ECTS
Quantitative Finances and Economics	at least 6 ECTS

- **Modelling activities**

Modelling activities (e.g. modelling seminar, summer school, study groups, industrial project, internships etc.)	6 ECTS
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- **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

Total ECTS for Master degree:

$$24-x \text{ (Block B)} + 48 \text{ (Block C)} + 9 \text{ (Modelling)} + 30 \text{ (Thesis)} + 9+x \text{ (free)} = 120$$

$(0 \leq x \leq 24)$

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 equilibrium 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 Autonomous University of Barcelona

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