



Lodz University
of Technology

Study programme

Faculty:	Faculty of Technical Physics, Information Technology and Applied Mathematics
Major:	Applied Mathematics
Level of study:	second-cycle programme (magister)
Form of study:	full-time studies
Academic year:	2026/27

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Basic information

Name of the field of study:	Applied Mathematics
Level of study:	second-cycle programme (magister)
Study profile:	general academic
Form of studies:	full-time studies
Duration of studies (number of semesters):	4
The number of ECTS points required to complete studies:	120
Total number of hours of classes:	1500
The number of ECTS points a student obtains as part of classes conducted with the direct participation of academic teachers or other persons conducting classes:	60
Professional title awarded to graduates:	magister
ISCED code:	0541
Language of study:	polish

Assigning the course to the disciplines to which the learning outcomes relate

Discipline	Percentage share
Maths	100%

Learning outcomes (in relation to the PQF)

No.	Learning outcome code	Learning Outcome Content	Reference to the universal characteristics of the first level of PRK	Reference to the second-level characteristics of the PRK, taking into account the second-level characteristics enabling the acquisition of engineering competences
1	2MAS1	Possesses in-depth, integrated and systematic knowledge of the fundamental areas of higher mathematics, enabling creative and critical use of this knowledge in specialized applications, taking into account the main development trends in a selected area: actuarial mathematics, data analysis or other areas of science and practice.	P7U_W	P7S_WG
2	2MAS2	Has extensive knowledge of entrepreneurship and the operation of companies, as well as selected legal and ethical aspects of professional activity, including intellectual property protection; knows and understands contemporary civilizational dilemmas related to the practice of mathematics.	P7U_W	P7S_WG, P7S_WK
3	2MAS3	Is able to performs advanced and complex mathematical reasoning and is able to relate selected mathematical issues to the context of other fields of science.	P7U_U	P7S_UW
4	2MAS4	Is able to select and apply advanced mathematical tools to solve complex theoretical and practical problems, or to use appropriate IT solutions in doing so.	P7U_U	P7S_UW
5	2MAS5	Is able to design solutions to complex mathematical problems and present research results in a clear and structured manner, justifying the motivation and reasoning leading to the results obtained; communicates with various audiences on specialist topics, assuming various roles, including that of a leader, when carrying out team tasks.	P7U_U	P7S_UW, P7S_UK, P7S_UO, P7S_UU
6	2MAS6	Is able to use a foreign language at a minimum B2+ level of the Common European Framework of Reference for Languages, including specialized terminology relevant to applied mathematics.	P7U_U	P7S_UK, P7S_UU
7	2MAS7	Identifies and takes into account the ethical and legal aspects of intellectual property protection and is ready to apply the basic principles of performing professional roles, including the principles of professional ethics.	P7U_K	P7S_KR
8	2MAS8	Is ready to critically evaluate his/her knowledge, recognizing its importance in solving complex cognitive and practical problems, and to use expert opinion in situations requiring in-depth competences.	P7U_K	P7S_KK
9	2MAS9	Is ready to act in an entrepreneurial manner and to responsibly fulfill social obligations.	P7U_K	P7S_KO

Matrix of course modules in relation to learning outcomes and curriculum content

No.	Course name	Program content	2MAS1	2MAS2	2MAS3	2MAS4	2MAS5	2MAS6	2MAS7	2MAS8	2MAS9
1	Machine Learning	Machine learning models and variants of the learning process; Theory of random forests; Techniques for evaluating predictive models; Ensemble learning algorithms, stochastic optimization techniques, selected clustering algorithms (DBSCAN, hierarchical methods); Nature-inspired artificial intelligence algorithms; Support Vector Machines; Introduction to neural networks; Selected XAI methods; Introduction to modern artificial intelligence – the use of large language models. Optionally, selected topics in finances, insurances, and decision theory.	x			x	x				
2	Probability Theory	Concept of probability and its properties, random variables and their characteristics (distribution functions, probability distributions, moments, moment-generating functions, independence), univariate and multivariate distributions, conditional expectation with respect to a sigma-algebra, conditional and compound distributions, strong laws of large numbers, the central limit theorem, and the basics of stochastic process theory (Markov chains, Markov processes, Poisson process, Brownian motion).	x			x					
3	Numerical Linear Algebra	Upper- and lower-triangular systems, Gaussian elimination, linear regression, polynomial interpolation, rank and determinant of a matrix, Kronecker-Capelli theorem, Gram-Schmidt orthonormalization, orthogonal projection, eigenvalues and eigenvectors, power method, Rayleigh quotients, principal component analysis.	x			x					
4	Introduction to Data Analysis	Overview of statistical data analysis methods, with examples of computer-based applications. Methods for examining univariate distributions from data. Basic statistical analyses of multivariate analysis: regression, classification, correspondence analysis, analysis of variance. Basics of cluster analysis. Graphical presentation of statistical data.	x			x					
5	Neural Networks and Deep Learning	Structure and learning mechanism of a neuron. Feed-forward neural networks – single-layer and multi-layer perceptrons. Bias-variance trade-off. Regularization methods, dropout, batch normalization. Convolutional neural networks, typical kernels. Recurrent neural networks, their structure and applications (e.g., in stock price prediction). Autoencoders. Generative models in the GAN architecture. Evaluation of neural network performance. Hyperparameter selection (fine-tuning). Preparation of image/audio data for processing by neural networks. Introduction to reinforcement learning – outline of the concept.	x			x	x				
6	Foreign Language for Specialist Purposes	Features and structure of scientific studies; analysis of specialized texts. Presentation and interpretation of research results and statistical data in the form of tables, graphs, etc. Development of language skills in the field of specialized vocabulary in applied mathematics necessary for writing scientific/specialized texts and preparing and delivering presentations in a foreign language. Development of teamwork skills using the project method.						x			
7	Functional Analysis with Topology	Methods of solving equations in Banach spaces, fundamental theorems of functional analysis (uniform boundedness principle, Hahn-Banach, Banach inverse operator theorem, closed graph theorem), applications in solving mathematical analysis problems, theory of Fourier series, concepts of general topology, weak topologies, weak convergence criteria.	x		x			x			
8	Mathematical Statistics	Concept of a statistical space, the fundamental theorem of statistics, sample moments and quantiles, order statistics, sufficient and complete statistics, classical and Bayesian estimation methods and their properties, correlation and regression analysis, confidence intervals, and statistical hypothesis testing.	x			x					

No.	Course name	Program content	2MAS1	2MAS2	2MAS3	2MAS4	2MAS5	2MAS6	2MAS7	2MAS8	2MAS9
9	Algorithms of Discrete Optimization	Overview of discrete optimization problems and methods for solving them: linear and integer programming, graph optimization algorithms, graph coloring, flow networks, task scheduling.	x			x					
10	Databases and Data Warehouses with Big Data Elements	Basics of databases and SQL (relational data modeling), data warehouses (warehouse architecture, dimensional models, ETL) and elements of Big Data (NoSQL systems, distributed processing, stream processing).	x			x	x				
11	Data Visualization and Business Intelligence	Characteristics of a good report: structure and components, objectives, options, flexibility. A report serving as a link between information analysis and analysis-based decisions. Creating a report with simulation elements and scenarios. Interactive environments focused on data visualization.				x					
12	Selected Applications of Bayesian Methods	The Bayes theorem, posterior distributions, Bayesian estimation (point estimation and interval estimation), arbitrary loss functions, hierarchical models, Bayesian prediction, Bayesian hypothesis testing, classification analysis, Bayesian networks, penalized regression methods (ridge regression, Lasso, Slope) – a Bayesian approach.	x			x					
13	Differential Equations	Dependence of solutions of ordinary differential equations on initial conditions. Stability in the Lapunov's sense, the linearization. Dynamical systems, classification of fixed points on the plane, limit sets. First integrals, systems with one degree of freedom. Initial value problems for partial differential equations (PDE) of order 1. The classification of PDEs of order 2, characteristics, canonical form, well-posed boundary value problems. Properties of harmonic functions, the Mean Value Theorem for harmonic functions, the Maximum Principle. Heat equation and wave equation. Weak solutions to the Poisson equation.	x		x						
14	Professional Ethics and Intellectual Property Protection	Descriptive and normative ethics. Theories of morality: absolutism, utilitarianism, deontology, relativism. Ethical dilemmas. Ethics and law. Professional ethics. Catalog of values and code of ethics. The concepts of sustainable development, CSR (corporate social responsibility), and ESG (enterprise reporting indicators). Intellectual property protection in international, European, and national law. European conventions on industrial property, including patents, trademarks, industrial designs, and copyrights. Counteracting violations. Copyright and innovation and competitiveness of enterprises. Case law of national and international courts.		x					x		x
15	Diploma Seminar	Preparation of a detailed work plan and identification of the necessary theoretical and methodological tools as well as bibliographic sources. During the classes, students will deliver presentations on successive sections of their theses, including definitions, theorems, proofs, and examples. Additionally, supplementary reports will be presented to expand the theoretical material related to the topics of the theses. A key component will be substantive discussions involving asking questions, identifying flaws and gaps in reasoning, and correcting both substantive and editorial errors. Finally, trial presentations of the forthcoming master's theses will be conducted.	x		x		x			x	
16	Philosophy of Mathematics	Argumentation and inference; applications of classical propositional calculus and classical predicate calculus; main trends in the philosophy of mathematics such as Platonism, logicism, intuitionism, formalism, fictionalism, structuralism; axiomatic approach to mathematical theories; theories and models; Gödel's theorems.			x						

No.	Course name	Program content	2MAS1	2MAS2	2MAS3	2MAS4	2MAS5	2MAS6	2MAS7	2MAS8	2MAS9
17	Practical Applications of Mathematics in Technology	Basic concepts and trends in contemporary mechanical engineering . The role of experimental research, analytical calculations and numerical modelling in technical applications. Methods and tools / software in mechanical engineering. Examples of analytical and simulation models and their application in mechanical engineering. Examples of research and test benches built on the basis of mathematical modelling and numerical simulations; the importance of validation of the modelling process.		x		x	x				
18	Principles of Company Operation and the Basics of Entrepreneurship	Objectives and types of enterprises, company environment, forms of business activity, basics of starting a business, company management, management functions, the concept of entrepreneurship, characteristics and role of an entrepreneur.		x							x
19	Final Project	The course involves completing a master's thesis under the supervision of a supervisor. The student independently analyzes the literature, formulates a research problem, and develops advanced skills in reasoning and mathematical modeling. The final product of the thesis is a coherent and reliable scientific text presenting research results or reasoning, demonstrating independent intellectual contribution and application of knowledge acquired during the course of study.	x		x		x			x	
20	Methods of Optimization in Finance and Insurance	Methods of evaluating investment projects (e.g. internal rate of return, modified internal rate of return). Investment or insurance portfolio management based on selected criteria, e.g. Markowitz model, CAPM model, utility theory, immunization, sensitivity analysis, calculation of insurance premiums and/or construction of reinsurance contracts.	x			x	x				
21	Methods of Pricing Financial Instruments	Risk measures, value-at-risk, coherent and convex risk measures. Basic concepts related to financial markets: arbitrage, payoff, portfolio, replicating strategy, complete market, martingale measure for the market, European and American options. Derivatives pricing. Basic theorems of financial mathematics. Binomial model of the capital market, Cox-Ross-Rubinstein formula. Continuous-time models, Black-Scholes formula.	x			x	x				
22	Data Analysis Methods and Functional Analysis in Insurance	Insurance insolvency risk models, including a regime-switching Sparre Andersen model (in particular discrete and continuous time model of insurer's insolvency) and related basic notions. The adjustment vector. Risk operator as a contraction. A vector of ruin probabilities as a fixed point of the risk operator; Banach Contraction Principle and its applications to approximate this vector. Recursive bounds for ruin probabilities. Implementation using IT methods and tools.	x			x	x				
23	Game Theory in Decision-Making	Basic concepts of game theory, single and multiplayer games, strategies and their optimality, equilibrium points, minimax theorems, algorithms for finding game values and optimal strategies, stochastic games, computer simulations allowing testing of various strategies, applications of game theory to decision-making problems.	x			x	x				
24	Abstract Methods in Modeling Phenomena	The course aims to deepen students' knowledge in functional analysis, descriptive set theory, or another area of advanced mathematics and its applications. In the functional analysis option, the course covers topics such as bases in linear spaces, linear independence, coordinate representations, Schauder bases and their properties, bases in Hilbert spaces, orthogonal and orthonormal bases, as well as isometries, the orthogonal projection theorem, and its applications. In the descriptive set theory option, the course includes the necessary elements of the theory of Polish spaces and definable sets, enabling the introduction of selection theorems (including Novikov's theorem, the Kuratowski-Ryll-Nardzewski theorem, and selection theorems for sets with large sections) and their applications. The precise content of the course is determined with regard to the interests of the students.	x			x	x				

No.	Course name	Program content	2MAS1	2MAS2	2MAS3	2MAS4	2MAS5	2MAS6	2MAS7	2MAS8	2MAS9
25	Applications of Dynamic Systems in Formal and Natural Sciences	The use of tools of the theory of dynamical systems in the study of selected mathematical models taken from exact and natural sciences, for example, problems such as: classification of critical points, phase portraits, critical points and their local and global stability, periodic trajectories and limit cycles and their stability, manifolds invariant; boundary sets, qualitative analysis of solutions. The use of IT solutions in the study of selected models, for example, problems such as: algorithms for solving non-linear systems of differential equations; stability and convergence of the above methods; computer simulations to study the behavior of dynamic systems; linearization of non-linear systems; study of the stability of systems with a large number of equations; numerical finding of eigenvalues using selected matrix decompositions, such as QR and SVD.	x			x	x				

ECTS - subjects

No.	Course name	ECTS	Subjects in the field of humanities and social sciences	Elective subjects	Profile items	Classes in a foreign language
1	Machine Learning	10		10		
2	Probability Theory	7			7	
3	Numerical Linear Algebra	6				
4	Introduction to Data Analysis	7			7	
5	Neural Networks and Deep Learning	10		10		
6	Foreign Language for Specialist Purposes	2		2		
7	Functional Analysis with Topology	6			6	6
8	Mathematical Statistics	7			7	
9	Algorithms of Discrete Optimization	5				
10	Databases and Data Warehouses with Big Data Elements	10		10		
11	Data Visualization and Business Intelligence	5				
12	Selected Applications of Bayesian Methods	7			7	
13	Differential Equations	6			6	
14	Professional Ethics and Intellectual Property Protection	2	2			
15	Diploma Seminar	3			3	
16	Philosophy of Mathematics	2	2			
17	Practical Applications of Mathematics in Technology	3				
18	Principles of Company Operation and the Basics of Entrepreneurship	2	2			
19	Final Project	20		20	20	
20	Methods of Optimization in Finance and Insurance	10		10		

No.	Course name	ECTS	Subjects in the field of humanities and social sciences	Elective subjects	Profile items	Classes in a foreign language
21	Methods of Pricing Financial Instruments	10		10		
22	Data Analysis Methods and Functional Analysis in Insurance	10		10		
23	Game Theory in Decision-Making	10		10		
24	Abstract Methods in Modeling Phenomena	10		10		
25	Applications of Dynamic Systems in Formal and Natural Sciences	10		10		

ECTS indicators

Name	Specialty: Data Analysis	Specialty: Risk Management in Finance and Insurance	Specialty: Applications of Mathematics in the Natural Sciences
The total number of ECTS credits that a student must obtain through elective courses (amounting to no less than 30% of the total ECTS credits required to obtain the qualification corresponding to the given level of study)	52/120 (43.33%)	52/120 (43.33%)	52/120 (43.33%)
The total number of ECTS credits to be earned by a student through courses in the fields of humanities or social sciences	6	6	6
The total number of ECTS credits that a student must obtain from courses related to research conducted at the university, amounting to more than 50% of the total ECTS credits required to graduate from a given level of study	63/120 (52.5%)	63/120 (52.5%)	63/120 (52.5%)

Methods of verifying and assessing learning outcomes

Verification of the achieved learning outcomes requires the application of diverse forms of student assessment, appropriate to the categories of knowledge, skills, and social competences to which these outcomes relate. The selection of appropriate tools depends on the specifics of the course and the form of instruction, and is specified in the syllabi of individual courses. The achievement of the required learning outcomes is verified through:

written assignments (exams, quizzes, reports, essays, projects, posters, thesis, etc.);
oral responses (oral knowledge tests, public speaking assignments such as delivering a paper, presentation, etc.);
practical and/or project-based tasks (team-based or individual);
observation and assessment of student activity during classes;
self-assessment and peer assessment (especially in the case of group projects);
a competency exam and a diploma examination.

Verification may be formative (conducted partially and repeatedly during the course) and/or summative (final assessment). The final result of the verification is expressed using the currently applicable grading scale.

The course coordinator or instructor is obliged, during the first class, to discuss the course syllabus and to define and formally communicate to students the methods of verification and the conditions under which learning outcomes will be assessed.

Professional internships

Not applicable

Specializations/degree paths offered within the study program

Specialty: Data Analysis

Specialty: Risk Management in Finance and Insurance

Specialty: Applications of Mathematics in the Natural Sciences

Characteristics of the course

Graduate profile

Graduates of the second-cycle Applied Mathematics program possess advanced, in-depth, and systematic knowledge of mathematics (including mathematical statistics), enabling a thorough understanding and creative application of mathematical methods in the analysis of complex theoretical and practical problems using IT techniques and tools. During their studies, students choose one of three specializations: Risk Management in Finance and Insurance, Data Analysis, or Applications of Mathematics in the Sciences.

The educational process encompasses not only advanced mathematical theories but also a broad spectrum of their applications in finance, insurance, data analysis, and other fields of study. Graduates can independently and critically select, modify, and integrate advanced mathematical, statistical, and IT methods to solve unique and complex problems, depending on their chosen specialization.

Graduates of the Risk Management in Finance and Insurance program possess in-depth competencies in the analysis and assessment of financial risk, the valuation of financial instruments, the calculation of insurance premiums and reserves, and the construction and optimization of investment portfolios. They understand the principles of financial markets and advanced investment strategies, including advanced concepts of modern ruin theory.

Graduates in the Data Analysis specialization possess in-depth knowledge and skills in extracting knowledge from data, including the use of advanced statistical methods, machine learning algorithms, and IT tools for analyzing large and complex data sets. They can independently formulate analytical and decision-making conclusions relevant to business, research, and decision-making processes.

Graduates in the Applications of Mathematics in the Exact Sciences specialization possess in-depth knowledge and skills in conducting advanced mathematical reasoning, as well as correctly formulating and solving problems related to modeling phenomena considered in the exact and natural sciences. This mathematical knowledge is complemented by a wide range of applications, including the ability to use IT tools to solve theoretical and practical mathematical problems.

Graduates in Applied Mathematics demonstrate a high level of independence, responsibility, and awareness of the limitations of the methods used. They can critically evaluate obtained results, interpret them in a broader context, and communicate them precisely and clearly, even in an interdisciplinary environment. Graduates are prepared to work in project teams, including taking on roles requiring initiative, independence and responsibility for the tasks carried out.

The relationship between the field of study and the university's strategy

The Applied Mathematics programme (second-cycle studies) is closely aligned with Lodz University of Technology's current development strategy, particularly in terms of improving the quality of education, developing scientific potential, and adapting the curriculum to the needs of the socio-economic environment. The curriculum provides students with in-depth and systematic knowledge of mathematics and its applications, and develops analytical, research, and application skills, which aligns with the university's strategic goal of educating highly qualified graduates prepared to address complex scientific and practical problems. The specializations offered enable the profiling of competencies in line with current and projected labor market needs and the development of modern fields of science and the economy.

The programme also supports the objectives of Lodz University of Technology's strategy to strengthen the interdisciplinarity of education and research, combining mathematical methods with issues of finance, insurance, data analysis, and the natural sciences. Preparing graduates to independently select and integrate mathematical, statistical, and computer science methods fosters collaboration with other disciplines and the economic environment. The learning outcomes for this major also support Lodz University of Technology's strategic goal of developing research and educating personnel for a knowledge-based economy, including preparing graduates to continue their education at postgraduate level and to actively participate in research and development projects. The social competencies developed, such as responsibility, independence, teamwork, and communication skills in an interdisciplinary environment, remain consistent with the university's mission and values as defined in its strategy.

Educational objectives and employment and continuing education opportunities

The aim of the second-cycle programme in Applied Mathematics is to prepare graduates to independently and responsibly analyze and solve complex mathematical problems, as well as to creatively apply mathematical methods in practical applications, including the use of advanced information technology. The educational process is focused on deepening theoretical knowledge and developing analytical and modeling skills, enabling the understanding, interpretation, and critical evaluation of phenomena and processes described using

mathematical tools. Regardless of the chosen specialization, graduates gain a significant expansion of specialized knowledge and skills compared to first-cycle programme in Applied Mathematics at the Faculty of FTiMS, Lodz University of Technology, as well as in-depth knowledge of classical mathematics, including, in particular, probability theory and mathematical statistics, differential equations, functional analysis, and topology. These developed competencies enable graduates to independently address highly complex problems and provide a solid foundation for continuing their education in the same or related scientific discipline. The education obtained prepares graduates to function flexibly in a changing labor market and to take up employment in financial and insurance institutions, analytical and consulting firms, research centers, as well as in industrial enterprises utilizing advanced quantitative and IT methods. Depending on their specialization, graduates are prepared to pursue professions such as mathematicians, statisticians, data analysts, financial analysts, financial or insurance advisors, as well as to take on other professional roles requiring high analytical competences and mathematical modeling skills.

Graduates of second-cycle studies in Applied Mathematics also possess competencies enabling further scientific and professional development, including undertaking doctoral studies and active participation in research and development projects that require independence, critical thinking, and responsibility for decision-making.

Description of the process and outcome of consultations on the proposed study program with the socio-economic environment

For over a decade, the Institute of Mathematics at Lodz University of Technology has been collaborating with companies in the finance, insurance, and data analysis sectors to evaluate and modify their study programmes. The current study programme was consulted with representatives of the following companies: mBank, epruf, Commerzbank, USP Zdrowie, and Allianz Polska, with a clearly positive conclusion.

The implementation of three specializations (Risk Management in Finance and Insurance, Data Analysis, and Applications of Mathematics in the Exact Sciences) in the second-cycle programme of studies in Applied Mathematics is a response to documented and widely described changes taking place in the labor market and in the structure of the modern economy.

Both OECD reports on future skills (including the OECD Skills Outlook) and periodic studies by the World Economic Forum (in particular, The Future of Jobs Report) point to the growing importance of analytical skills, the ability to solve complex problems, and working with data in the modern economy. These reports emphasize that analytical thinking, quantitative competencies, and the ability to use digital and analytical tools are among the key skills sought by employers in many economic sectors. The World Economic Forum also points out that professional roles related to data analysis and digital technologies are among the professions expected to grow in importance in the coming years. At the same time, the literature on quantitative finance and insurance mathematics clearly indicates the key role of mathematical and statistical methods in risk management processes, the valuation of financial instruments, and the implementation of applicable regulatory requirements in the financial and insurance sectors.

In turn, literature on the exact and technical sciences emphasizes the importance of mathematics as a universal language for describing phenomena and processes and as a tool enabling the conduct and integration of interdisciplinary research.

The proposed specializations are therefore consistent with both global trends in the development of a knowledge- and data-driven economy and with the expectations of employers and external stakeholders, expressed during consultations with companies collaborating with the Institute of Mathematics of Lodz University of Technology.

The feedback from company representatives (epruf, mBank, Commerzbank, Allianz, USP Zdrowie) confirmed the validity of the structure of the second-cycle programme in Applied Mathematics. It was emphasized that the programme is appropriately optimized and adapted to the realities of the labor market – on the one hand, it provides in-depth mathematical education necessary for professional mathematicians (as well as for undertaking third-cycle studies), regardless of the chosen specialization, while on the other, the rationally planned study schedule allows students to simultaneously undertake professional work, internships, and apprenticeships. It was noted that the modern economy increasingly relies on the processing, analysis, and interpretation of large data sets, both in the private sector (IT, finance, insurance, e-commerce, industry) and the public sector (administration, healthcare, education). The dynamic development of areas such as data science, machine learning, artificial intelligence, and business intelligence generates a sustained demand for highly qualified specialists with a solid mathematical foundation and advanced analytical skills. At the same time, the importance of conducting classes using current IT tools commonly used in enterprises, including modern programming environments, analytical tools, and cloud solutions, was emphasized. This approach strengthens the practical dimension of education and increases graduates' competitiveness in the labor market.

Description and justification for the introduction of the specialization:

The Risk Management in Finance and Insurance specialization was designed to meet the growing demand for highly qualified specialists

capable of quantitative risk analysis in the increasingly complex financial and insurance markets. The ongoing globalization of markets, the dynamic development of new financial instruments, tightening regulatory requirements, and the growing importance of quantitative models in decision-making processes make competencies in financial and insurance mathematics crucial to the functioning of financial institutions. Graduates of this specialization possess advanced knowledge of financial mathematics, insurance mathematics, and the principles of financial and insurance markets. They possess the skills to manage financial risk and conduct broadly understood actuarial analysis, using modern IT and computational tools. These competencies are directly applicable in the banking and insurance sectors, as well as in financial institutions. As part of their education, graduates acquire skills in calculating insurance premiums and reserves, estimating credit costs, valuing securities, and analyzing and measuring the associated risks. They can also construct and optimize investment portfolios and analyze and forecast phenomena occurring in the insurance market. This specialization meets the needs of employers seeking professionals who combine a solid theoretical foundation with practical preparation for work in a regulated environment strongly based on quantitative analysis.

The Data Analysis specialization addresses one of the strongest and most enduring trends in the contemporary labor market: the growing importance of data as a fundamental decision-making resource in the economy. The foundation of education in this specialization is mathematics, statistics, and computer science, with a particular emphasis on statistical data analysis and information systems for extracting knowledge from data. Graduates possess thorough knowledge and skills in data mining methods and algorithms, machine learning, and elements of artificial intelligence. The specialization program combines a solid theoretical foundation with intensive practical training, covering topics such as machine learning, neural networks and deep learning, databases and data warehouses, Big Data elements, data visualization, and business intelligence tools. This program structure allows for effective preparation of graduates for work in analytical and design teams.

According to the opinions of representatives of the socio-economic environment, this specialization is justified, current, and fully meets the needs of the labor market. The rationally planned number of hours of classes allows students to simultaneously gain professional experience through internships, placements, and project work. The competencies acquired within the specialization are universal and transferable, increasing graduates' resilience to the dynamic technological and organizational changes occurring in the labor market.

The Applications of Mathematics in the Exact Sciences specialization was designed for students interested in the in-depth, applied use of mathematics in the exact sciences and in research and development activities. It provides solid knowledge and skills in precise mathematical reasoning, correct problem formulation, and the selection of appropriate methods for solving them.

Graduates' mathematical knowledge is supplemented with a wide range of applications, including the ability to use computer and computational tools in solving theoretical and practical mathematical problems. Graduates can use advanced mathematical methods to describe, interpret, and analyze various processes occurring in the exact sciences and engineering. This specialization provides an education that allows for a flexible response to the needs of the labor market and prepares graduates for work in research, analytical, and industrial institutions involved in the creation, analysis, and modification of process models. It also provides a solid foundation for continuing education in doctoral schools and for working in interdisciplinary teams where mathematics serves as a tool integrating various areas of knowledge.

Summary.

The three specializations offered in the second-cycle program in Applied Mathematics at Lodz University of Technology are strongly justified both by the detailed characteristics of learning outcomes and the unequivocally positive opinions of representatives of the socio-economic environment. The proposed specializations respond to current and long-term needs of the labor market, strengthen the practical and applied dimension of the studies, and increase the attractiveness of the workforce.

Description of competencies expected from a candidate applying for admission to studies

In accordance with the Recruitment Resolution in force at the Lodz University of Technology.

The unit organizing education

Faculty of Technical Physics, Information Technology and Applied Mathematics

Education program

Semester 1

Course	Number of hours	ECTS points	Form of verification	Obligatory
Probability Theory	Tutorials: 45 Lecture: 30	7	Exam	Obligatory
Numerical Linear Algebra	Laboratory classes: 30 Lecture: 30	6	Graded assignment	Obligatory
Introduction to Data Analysis	Laboratory classes: 30 Lecture: 30	7	Graded assignment	Obligatory
Sum	195	20		

Specialty: Data Analysis

Course	Number of hours	ECTS points	Form of verification	Obligatory
Machine Learning	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Specialty: Risk Management in Finance and Insurance

Course	Number of hours	ECTS points	Form of verification	Obligatory
Methods of Optimization in Finance and Insurance	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Specialty: Applications of Mathematics in the Natural Sciences

Course	Number of hours	ECTS points	Form of verification	Obligatory
Game Theory in Decision-Making	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Semester 2

Course	Number of hours	ECTS points	Form of verification	Obligatory
Foreign Language for Specialist Purposes	Tutorials: 45	2	Graded assignment	Obligatory subjects to choose from
Functional Analysis with Topology	Tutorials: 30 Lecture: 30	6	Exam	Obligatory
Mathematical Statistics	Tutorials: 40 Lecture: 30	7	Exam	Obligatory
Algorithms of Discrete Optimization	Laboratory classes: 30 Lecture: 30	5	Graded assignment	Obligatory
Sum	235	20		

Specialty: Data Analysis

Course	Number of hours	ECTS points	Form of verification	Obligatory
Neural Networks and Deep Learning	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Specialty: Risk Management in Finance and Insurance

Course	Number of hours	ECTS points	Form of verification	Obligatory
Methods of Pricing Financial Instruments	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Specialty: Applications of Mathematics in the Natural Sciences

Course	Number of hours	ECTS points	Form of verification	Obligatory
Abstract Methods in Modeling Phenomena	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Semester 3

Course	Number of hours	ECTS points	Form of verification	Obligatory
Data Visualization and Business Intelligence	Laboratory classes: 30 Lecture: 25	5	Graded assignment	Obligatory
Selected Applications of Bayesian Methods	Laboratory classes: 30 Lecture: 30	7	Graded assignment	Obligatory
Differential Equations	Tutorials: 30 Lecture: 30	6	Exam	Obligatory
Professional Ethics and Intellectual Property Protection	Lecture: 30	2	Graded assignment	Obligatory
Sum	205	20		

Specialty: Data Analysis

Course	Number of hours	ECTS points	Form of verification	Obligatory
Databases and Data Warehouses with Big Data Elements	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Specialty: Risk Management in Finance and Insurance

Course	Number of hours	ECTS points	Form of verification	Obligatory
Data Analysis Methods and Functional Analysis in Insurance	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Specialty: Applications of Mathematics in the Natural Sciences

Course	Number of hours	ECTS points	Form of verification	Obligatory
Applications of Dynamic Systems in Formal and Natural Sciences	Project work: 90 Lecture: 25	10	Graded assignment	Obligatory specialization courses
Sum	115	10		

Semester 4

Course	Number of hours	ECTS points	Form of verification	Obligatory
Diploma Seminar	Seminar: 45	3	Graded assignment + exam	Obligatory
Philosophy of Mathematics	Lecture: 20	2	Graded assignment	Obligatory

Course	Number of hours	ECTS points	Form of verification	Obligatory
Practical Applications of Mathematics in Technology	Lecture: 30	3	Graded assignment	Obligatory
Principles of Company Operation and the Basics of Entrepreneurship	Lecture: 20	2	Graded assignment	Obligatory
Final Project	Diploma Thesis: 0	20	Pass	Obligatory subjects to choose from
Sum	115	30		