Institute of Automation and Information Technology
Department of Higher Mathematics and Modeling

EDUCATIONAL PROGRAM

7M06110 - Digital modeling

code and name of the educational program

Code and Classification of Education Area: 7M06
Information and Communication Technology
Code and classification of areas of training: 7M061
Information and Communication Technologies
Group of educational programs: M094
Information Technology
NRC level: 7M
OPC level: 7
Study period: 2 years
Credit volume: 120

Almaty 2024

Educational program 7M06110 – «Digital modeling» approved at the meeting of the Academic Council of KazNRTU named after K.I. Satpayev.
Protocol No.12 of "22" April 2024 year.

Considered and recommended for approval at the meeting of the Educational-Methodical Council of KazNRTU named after K.I. Satpayev.
Protocol No. 6 of "19" April 2024 year.

Educational program 7M06110 – «Digital modeling» developed by the academic committee for the direction 7M061 "Information and communication technologies".

Name and surname	Degree/ academic title	Position	Place of work	Sign
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Table of contents

List of abbreviations and designations

EP - educational program,
LO - learning outcomes,
DG - Digital modeling,
IEP - individual educational plan

1. Description of the educational program

The educational program 7M06110 – «Digital modeling» is aimed at training masters who can independently solve a wide range of engineering problems using modern analytical, numerical and experimental methods and methods of mathematical and computer modeling.

The educational program is designed to train specialists in mathematical and computer modeling of various processes and complex systems, to master competitive knowledge and the ability to apply them to create new methods and knowledge in mathematical and computer modeling of three-dimensional objects, and to solve applied problems arising in physics, chemistry, biology, economics, etc. The specialists will also be able to model various problems arising in theoretical computer science.

The program aims to train highly qualified specialists in mathematical computer modeling with innovative problem-solving skills in their area of expertise. Graduate students will also apply their knowledge to the analysis of various problems arising in physics, economics, finance, biology, computer science, and engineering.

The curriculum of the educational program 7M06110 – «Digital modeling» was developed taking into account the curricula of the educational program "Computational and mathematical engineering" of the master's degree program of famous research and engineering universities of the world, such as *Stanford University,* Universitat Obertade Catalunya and the educational program "Mathematical Modeling, Programming and Artificial Intelligence" of the master's degree program at St Petersburg State University. The curriculum is fully consistent with modern trends in the development of mathematical and computer modeling, information technology and the needs of the economy and science of Kazakhstan.

The educational program consists of core courses in mathematical modeling and coursework in programming algorithm design and construction, extensive and in-depth electives, and seminars. The core courses provide instruction in mathematical and computational tools applicable to a wide range of scientific, industrial, and engineering disciplines, and expand and deepen elective courses. The computer modeling requirement ensures mastery of scientific methods and professional skills. Seminars highlight new research in engineering and science.

The program is notable for the fact that it combines information and technological fundamentals with practical modeling capabilities. In the process of training, special attention is paid to the acquisition by graduates of profound knowledge in relevant areas, the ability to develop mathematical, physical and computer models of engineering problems and mastering the skills of independent research. The acquired knowledge and experience in computer modeling and research using modern computational and information technologies will allow graduates to quickly integrate into the work process, quite easily master a wide range of new technologies.

Graduates get practical training in such companies of Kazakhstan as JSC Kazatomprom, JSC KazMunayGas, JSC KazdorNII, the Institute of Mathematics and Mathematical Modeling, etc. Under the program of academic mobility, undergraduates have the opportunity to undertake internships in leading engineering universities in Europe and Russia.

All levels of training are taught by highly qualified faculty, including graduates of universities in Europe, Russia, and other countries.

Graduates may choose a variety of career paths. Some may go directly into industry as practicing engineers, while others may pursue doctoral studies in mathematical and computer modeling. Graduates may be employed by banks and insurance companies, consulting firms, educational and research institutions, and other companies that use mathematical modeling, computer modeling, and applied mathematics in their work.

The educational program of the master's degree "Digital Modeling" is the second level of qualification of the three-tier system of higher education, it lays the foundation for doctoral programs.

2. Goal and objectives of the educational program

Purpose of the EP: The purpose of the educational program "Digital Modeling" is to train highly qualified specialists with relevant competencies of masters in the field of mathematical and computer modeling, creation and use of new effective methods of information processing, mathematical models of complex processes and objects, development and application of modern mathematical methods and software. As a result of graduation, graduates will be able to work as specialists in the field of technology construction and research of mathematical models of a wide variety of systems and processes, allowing to predict the evolution of the studied systems, and thereby verify the correctness of the decisions taken.

EP Objectives: Objectives of the educational program:

- training a competitive generation of technical masters in mathematical and computer modeling for the labor market, proactive, able to work in a team, with high personal and professional competencies;
- integration of educational and scientific activities;
- establishing partnerships with leading universities in the near and far abroad in order to improve the quality of education;
- expansion of contacts with customers of educational services, employers in order to determine the requirements for the quality of training of masters, courses, seminars, workshops, internships, practical training.

The content of the educational program " Digital Modeling " is implemented in accordance with the credit technology of education and is carried out in the state, Russian and English languages. The educational program will allow the implementation of the principles of the Bologna Process. Based on the choice and independent planning of the sequence of disciplines by master students, they independently form the IEP for each semester according to the Working curriculum and the Catalogue of elective disciplines. The volume of mathematical, natural

science, basic and language disciplines is increased in the educational program.

Graduates undergo practical training in commercial, state and departmental structures. Under the program of academic mobility the best students have the opportunity to study at leading foreign universities in the relevant program.

3. Requirements for assessing the learning outcomes of the educational program

List of competencies

General competencies

- English language skills for: search for scientific and technical information; work with scientific and technical literature; oral and written communication with a native speaker on a professional topic and in real-life situations.
- Mastery of critical systems thinking, transdisciplinarity, and cross-functionality.
- ICT competencies, the ability to develop software using algorithmic languages.
- Possess the skills of: independent learning; deepening your knowledge; being open to new information; thinking systematically and exercising your own judgment.
- The ability to be tolerant of another nationality, race, religion, culture; the ability to engage in intercultural dialogue.
- Mastery of communication skills, ability to cooperate and work in a team.
- Ability to work in a mode of high uncertainty and rapidly changing task conditions; work with customer requests.
- The possession of a broad social, political and professional outlook; ability to use data from various sources and special literature, analyze and critically evaluate historical facts and events.
- Mastery of the basics of entrepreneurship and business economics, readiness for social mobility.

Professional competencies

- Mastery of fundamental knowledge of mathematics, physics, and scientific principles and the ability to use them in solving engineering problems.
- Ability to independently develop adequate physical and mathematical models, computer modeling algorithms.
- Ability to use mathematical and computer models of technological processes for independent research.
- Ability to develop new mathematical models of information technology.
- Ability to work with high-tech laboratory and research equipment.
- Mastery of algorithmic languages and programming technology using object-oriented programming of mathematical and numerical models of physical processes and engineering problems.

- Mastery of mathematical modeling and machine learning methods and computer modeling skills to work as a designer in mechanical engineering, energy, transportation, chemical production.
- Possession of methodology: system analysis; design and decision making in complex and professional situations; ways of communication and reconciliation of points of view; execution and presentation of analytical and project documentation.

Learning outcomes

LO 1 - Use of logical programming skills in various languages achieved through lab work and exams based on problem solving;
LO 2 - In-depth knowledge of differential equations and solving applied problems;
LO 3 - Development of various types of mathematical models and simulations, including dynamic systems, statistical models, differential equations, game-theoretic models (calculus, ordinary differential equations, numerical methods, statistics, etc.) and practical modeling course;
LO 4 - Application of mathematical and computer modeling methods to solve scientific, applied, industrial and technological problems using professional software, computer graphics, visualization and development of own software packages;
LO 5 - Basic knowledge of financial mathematics, number theory applications, data management and analysis, study of elective courses;
LO 6 - Analysis of collected information and presentation of research results achieved through work on individual and group projects.
LO 7 - Search and study scientific and technical information on mathematical and computer modeling and be able to express written and oral opinions on the topic in Kazakh (Russian) and English;
LO 8 - Know the basics of management psychology and the basics of pedagogy of higher education, have teaching skills, know and critically analyze sources on the history and philosophy of science;
LO 9 - Be able to program in modern algorithmic programming languages, master the method of machine learning and data analysis;
LO 10 - Be able to model dynamic systems and apply it to solve vibration and control problems.

Learning strategy

The strategy of the educational program "Digital modeling" is focused on training highly qualified specialists with fundamental knowledge in the fields of natural science, engineering mechanics and computer modeling to work in the field of high technology, taking into account current trends in the development of science in general and mathematical modeling in particular.

In the process of training special attention is paid to learning mathematical, numerical and computer modeling methods, proven software for solving and

researching a wide range of engineering problems by masters. To implement this goal, the structure of classes of almost all specialized disciplines includes both laboratory and practical classes, i.e. theoretical knowledge of students is firmly consolidated by the skills of their practical application.

In the course of graduates' dissertations in the educational program, the main attention is paid to imparting to graduates the skills to develop independently or in teams physical or virtual models of complex mechanical, physical and biochemical processes and phenomena, to create computer codes or apply modern software for their research.

Mastery of fundamental knowledge in a variety of fields and computer modeling skills will allow graduates to integrate relatively easily into the workflow of almost any area of industry and learn a wide range of new technologies fairly quickly.

4. Passport of the educational program

4.1 General information

№	Field name	Note
1	Code and classification of the field of education	7M06 Information and Communication Technology
2	Code and classification of training areas	7M061 Information and Communication Technology
3	Group of educational programs	M094 Information Technology
4	Name of educational program	7M06110 - Digital modeling

5	Brief description of the educational program	The educational program "7M06110 - Digital modeling" is aimed at training masters who can independently solve a wide range of engineering problems using modern analytical, numerical and experimental methods and methods of mathematical and computer modeling. The educational program is designed to train specialists in mathematical and computer modeling of various processes and complex systems, to master competitive knowledge and the ability to apply them to create new methods and knowledge in mathematical and computer modeling of three-dimensional objects, and to solve applied problems arising in physics, chemistry, biology, economics, etc. The specialists will also be able to model various problems arising in theoretical computer science. The program aims to train highly qualified specialists in mathematical computer modeling with innovative problem-solving skills in their area of expertise. Graduate students will also apply their knowledge to the analysis of various problems arising in physics, economics, finance, biology, computer science, and engineering. The curriculum of the educational program "7M06110 - Digital modeling" was developed taking into account the curricula of the educational program "Computational and mathematical engineering" of the master's degree program of famous research and engineering universities of the world, such as Stanford University, Universitat Obertade Catalunya and the educational program "Mathematical Modeling, Programming and Artificial Intelligence" of the master's degree program at St Petersburg State University. The curriculum is fully consistent with modern trends in the development of mathematical and computer modeling, information technology and the needs of the economy and science of Kazakhstan. The educational program consists of core courses in mathematical modeling and coursework in programming algorithm design and construction, extensive and in-depth electives, and seminars. The core courses provide instruction in mathematical and computational tools applicable to a wide range of scientific, industrial, and engineering disciplines, and expand and deepen elective courses. The computer modeling requirement ensures mastery of scientific methods and professional skills. Seminars highlight new research in engineering and science. All levels of training are taught by highly qualified faculty, including graduates of universities in Europe, Russia, and other countries.

		Graduates may choose a variety of career paths. Some may go directly into industry as practicing engineers, while others may pursue doctoral studies in mathematical and computer modeling. The educational program of the master's degree "Digital modeling" is the second level of qualification of the three-tier system of higher education; it lays the foundation for doctoral programs.

6	Purpose of the EP	The purpose of the educational program "Digital modeling " is to train highly qualified personnel with relevant competencies of masters in the field of mathematical and computer modeling, creation and use of new effective methods of information processing, mathematical models of complex processes and objects, development and application of modern mathematical methods and software. As a result of graduation, graduates will be able to work as specialists in the field of technology construction and research of mathematical models of a wide variety of systems and processes, allowing to predict the evolution of the studied systems, and thereby verify the correctness of the decisions taken.
7	Type of EP	Master's Degree
8	NRC level	7M
9	Level on OCR	7
10	Distinctive features of the EP	The program is notable for the fact that it combines information-technology fundamentals with practical modeling capabilities. In the process of training, special attention is paid to the acquisition by graduates of profound knowledge in relevant areas, the ability to develop mathematical, physical and computer models of engineering problems and mastering the skills of independent research. The acquired knowledge and experience in computer modeling and research using modern computational and information technologies will allow graduates to quickly integrate into the work process, quite easily master a wide range of new technologies.

11	List of competencies of the educational program:	General competencies • English language skills for: search for scientific and technical information; work with scientific and technical literature; oral and written communication with a native speaker on a professional topic and in real-life situations. • Mastery of critical systems thinking, transdisciplinarity, and cross-functionality. • ICT competencies, the ability to develop software using algorithmic languages. • Possess the skills of independent learning; deepening your knowledge; being open to new information; thinking systematically and exercising your own judgment. • The ability to be tolerant of another nationality, race, religion, culture; the ability to engage in intercultural dialogue. • Mastery of communication skills, ability to cooperate and work in a team. • Ability to work in a mode of high uncertainty and rapidly changing task conditions; work with customer requests. • The possession of a broad social, political and professional outlook; ability to use data from various sources and special literature, analyze and critically evaluate historical facts and events. • Mastery of the basics of entrepreneurship and business economics, readiness for social mobility. Professional competencies • Mastery of fundamental knowledge of mathematics, physics, and scientific principles and the ability to use them in solving engineering problems. • Ability to independently develop adequate physical and mathematical models, computer modeling algorithms. • Ability to use mathematical and computer models of technological processes for independent research. • Ability to develop new mathematical models of information technology. • Ability to work with high-tech laboratory and research equipment. • Mastery of algorithmic languages and programming technology using object-oriented programming of mathematical and numerical models of physical processes and engineering problems. • Mastery of mathematical modeling and machine learning methods and computer modeling skills to work as a designer in mechanical engineering, energy, transportation, chemical production. • Possession of methodology: system analysis; design and decision making in complex and professional situations; ways of communication and reconciliation

		of points of view; execution and presentation of analytical and project documentation.

12	Learning outcomes of the educational program:	LO1 - Use of logical programming skills in various languages achieved through lab work and exams based on problem solving; LO2 - In-depth knowledge of differential equations and solving applied problems; LO3 - Development of various types of mathematical models and simulations, including dynamic systems, statistical models, differential equations, game-theoretic models (calculus, ordinary differential equations, numerical methods, statistics, etc.) and practical modeling course; LO4 - Application of mathematical and computer modeling methods to solve scientific, applied, industrial and technological problems using professional software, computer graphics, visualization and development of own software packages; LO5 - Basic knowledge of financial mathematics, number theory applications, data management and analysis, study of elective courses; LO6 - Analysis of collected information and presentation of research results achieved through work on individual and group projects. LO7 - Search and study scientific and technical information on mathematical and computer modeling and be able to express written and oral opinions on the topic in Kazakh (Russian) and English; LO8 - Know the basics of management psychology and the basics of pedagogy of higher education, know the skills of teaching, know and critically analyze sources on the history and philosophy of science; LO9 - Be able to program in modern algorithmic programming languages, master the method of machine learning and data analysis; LO10 - Be able to model dynamic systems and apply it to solve vibration and control problems.
13	Form of training	Full-time
14	Duration of training	2 years
15	Volume of credits	120
16	Languages of instruction	Kazakh, Russian, English
17	Academic degree	Master
18	Developer(s) and authors:	Ualiev J.R., Azhibekova A.S., Lukpanova L.H.

4.2 Interrelation of achievability of the learning outcomes of the educational program and academic disciplines

№	Name of discipline	Brief description of the discipline	Number of credits	Formable learning outcomes (codes)									
				LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8	LO9	LO10
Cycle of basic disciplines The university component													
1	Foreign language (professional)	The course is designed for undergraduates of technical specialties to improve and develop foreign language communication skills in the professional and academic sphere. The course introduces students to the general principles of professional and academic intercultural oral and written communication using modern pedagogical technologies (round table, debates, discussions, analysis of professionally oriented cases, design).	5							V			
2	Management Psychology	The discipline examines the modern role and content of psychological aspects in managerial activity. Examines the improvement of psychological literacy of the trainee in the implementation of professional activity. Self-improvement in the field of psychology and studies the composition and structure of managerial activity, both at the local level and in foreign. The psychological peculiarities of modern managers are considered.	3								V		

3	History and Philosophy of Science	The subject of philosophy of science, dynamics of science, specificity of science, science and pre-science, antiquity and the formation of theoretical science, the main stages of the historical development of science, features of classical science, non-classical and post-classical science, philosophy of mathematics, physics, engineering and technology, specificity of engineering science, science ethics, the social and moral responsibility of scientists and engineers.	3								v		
4	Higher school pedagogy	Within the framework of the course master students will master methodological and theoretical bases of pedagogics of higher school, learn how to use modern pedagogical technologies, plan and organize the processes of training and education, master communicative technologies of subject-subject interaction of a teacher and master student in the educational process of higher school. Also, master students will study human resource management in educational organizations (on the example of a higher school).	3								v		
Cycle of basic disciplines Optional component													

5	Numerical methods for solving applied problems	The discipline "Numerical methods for solving applied problems" is devoted to practical aspects of the numerical solution of various applied problems using mathematical methods. Practical aspects of mathematical formulation of applied problems, the choice and numerical implementation of mathematical methods of their solution are considered. Thus special attention is paid to necessity of taking into account specificity of investigated problems both at statement of applied problems and at development of methods of their numerical analysis.	5		v							
6	Machine learning methods	Objectives of the discipline: to form theoretical knowledge on the basics of machine learning to build formal mathematical models and interpretation of simulation results; to develop skills for the practical application of machine learning methods to build formal mathematical models and interpretation of simulation results in solving applied problems in various applied areas. Machine Learning Methods is a broad subsection of Artificial Intelligence that studies methods of constructing algorithms capable of learning.	5								v	

7	Geometric and computer modeling	The purpose of the discipline is the gradual formation of students of the following knowledge, skills and abilities: - studying and mastering the basic concepts, methods and algorithms used in the development of computer graphics; - forming a view of computer graphics as a systematic scientific and practical activity, which is both theoretical and applied; - formation of basic theoretical concepts underlying computer graphics, mastering the features of perception of raster images, methods of quantization and discretization of images; - acquisition of knowledge about the structure of software and implementation of computer algorithms	5				v						
8	Python for Deep Machine Learning	The objectives of the discipline is to familiarize with modern approaches to the construction, training and use of recognition and classification systems based on machine learning methods formation of professional competence of undergraduates. The content of the discipline is aimed at mastering algorithms and methods of deep learning (deep learning) - a special section in machine learning (machine learning); formation of skills and abilities in solving practical problems using deep learning methods.	5						v				

9	Information technologies in the oil and gas industry	The purpose of the discipline is to familiarize undergraduates with the existing achievements of information technology in the context of their use in the oil and gas industry; getting the necessary knowledge on the implementation, use and prospects for IT at the stages of exploration, production, transportation and processing of oil and gas.	5	v									
10	Calculus of variations	Studying the basic methods of solving classical variational problems. Raising the level of professional competence in solving optimization problems. Further formation of master students' skills of abstract mathematical thinking and the ability to apply it in specific problems, increasing their mathematical culture.	5			v							
Cycle of major disciplines Higher education component													

11	Parallel computing	The aim of the course is to acquire knowledge and skills on the basics of parallel programming and parallel data processing using computer facilities. Course objectives: to teach methods of parallel information processing and presentation of parallel algorithms; to familiarize students with computer architecture; to form means of specification of parallel processes; to teach parallel programming languages; to master methods of automatic paralleling of sequential algorithms.	5					v					
12	Models of financial mathematics	The discipline "Models of Financial Mathematics" provides for the solution of the following tasks: mastering by students of the main interrelated parameters of any credit or commercial operation (the size and terms of deposits, loans, interest rates on them); obtaining knowledge about the quantitative relationships between these parameters and obtaining certain financial results based on them.	5					v					
13	Modeling in porous media	The purpose of teaching the discipline "Modeling in porous media" consists in the theoretical development of the main sections, in understanding and the possibility of applying this knowledge in the professional activities of the engineer in building computer models of the fields, reflecting the most realistic picture of the field.	5										v

14	Interfaces for multi-core systems	The aim of the study: the formation of master's theoretical knowledge and practical skills in the use of modern computing complexes and software to solve a wide range of problems in various fields. The course examines the features of the architecture of graphics processors, the principles of organization of hybrid computing systems based on graphics processors, classes of tasks suitable for effective execution on graphics processors.	5						v				
15	Machine Learning & Deep Learning	The course focuses on deep learning models. As a domain within machine learning, deep learning models illustrate a quantitative-qualitative transition. New models and their properties require separate study and practice in tuning the meta-parameters of such models. This course covers the basics of deep learning, neural networks, convolutional networks, RNN, LSTM, Adam, Dropout, BatchNorm, Xavier/He initializations.	5	v									
Cycle of core disciplines Optional component													

16	Numerical solution of the fluid motion equation by the finite difference method	The objectives of the discipline "Numerical solution of the equation of motion of the fluid by finite-difference method" are: study and practical development of the main stages of mathematical modeling of hydrodynamic processes, including the physical statement of the problem, the choice of mathematical model and formulation of the initial-edge problem, the construction of a grid model of the area, the choice or development of grid approximations. Various algorithms for constructing finite-difference and finite-element meshes are considered. The finite difference, finite volume and finite element methods are studied.	5			v							
17	Geostatistics	Concepts and methods important for modeling heterogeneity and uncertainty in a reservoir model. Three-dimensional reservoir modeling.	5										v
18	Applied Information Theory	Purpose of mastering: the formation of ideas about the theory of information as a universal language of science, the means of modeling phenomena and processes, the ideas and methods of coding and cryptography; development of logical thinking, spatial imagination, algorithmic culture, critical thinking at the level necessary for future professional activities, for continuing education and self-education; mastering the theoretical knowledge and skills necessary in everyday life, for the study of related disciplines of the professional cycle.	5									v	

19	Fuzzy and neural network modeling	An artificial neural network is a computational architecture for processing complex data using multiple interconnected processors and computational paths. Artificial neural networks, created by analogy with the human brain, are able to train and analyze large and complex data sets that are extremely difficult to process using more linear algorithms.	4									v	
20	Digital hydrodynamic modeling	This course covers the study of physical principles, implementation technology and methods for interpreting the results of modern complex hydrodynamic well tests.	5						v				