NCJS«KAZAKHNATIONALRESEARCH TECHNICAL UNIVERSITY
named afterK.I.SATBAYEV»

Institute of Energy and Mechanical Engineering named after A. Burkitbaev
Department of Mechanical Engineering

EDUCATIONAL PROGRAM

7M07145 - Mechanical Engineering and Modeling

Code and classification of the field of education: 7M07 Engineering, manufacturing and construction industries
Code and classification of training areas: 7M071 - Engineering and Engineering
Group of educational programs: M103 - Mechanics and metal working
The level of the NRK: 7
ORC Level: 7
Duration of study: 2 years
Volume of credits: 120

Almaty 2024

Educational program 7M07145 - Mechanical Engineering and Modeling approved at the Meeting of the Academic Council of KazNRTU named after K.I.Satpayev.

Protocol No. 12 dated April 22, 2024.

Reviewed and recommended for approval at a meeting of the Educational and Methodological Council of KazNRTU named after K.I.Satpayev.

Protocol No. 6 dated April 19, 2024.

Educational program 7M07145- Mechanical Engineering and Modeling developed by the academic committee for the group of educational programs: M103 - Mechanics and metal working

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List of abbreviations and designations

EP - educational program,
LO – learning outcomes,
FM – Fluid Mechanics

1. Description of the educational program

The educational program **7M07145 - Mechanical Engineering and Modeling** is aimed at training Masters able to solve independently a wide range of mechanical engineering problems by modern analytical, numerical and experimental methods, including mathematical and computer modeling.

The curriculum of the educational program **7M07145 - Mechanical Engineering and Modeling** was developed based on the curricula of the Master's degree educational program "Mechanical Engineering" of world leader research and engineering universities, such as Stanford University, Massachusetts Institute of Technology – MIT, Georgia Institute of Technology, Nanyang Technological University (Singapore) and the Master's degree educational program "Mechanics and Mathematical modeling" of Bauman Moscow State Technical University and Peter the Great St. Petersburg Polytechnic University. The curriculum fully corresponds to modern trends in mechanical engineering, information technology and the demands of the economy and science of Kazakhstan.

A feature of the program is the combination of engineering fundamentals with practical design skills. In the course of training, special attention is paid to the acquisition by graduates of in-depth knowledge in relevant areas of engineering mechanics, the ability to develop mathematical, physical and computer models of engineering problems and mastering the skills of independent research. The acquired knowledge as well as experience in programming and research using modern information technologies allow graduates to quickly integrate into the workflow of modern engineering and master a wide range of new technologies.

Graduates will practice in such companies as Kazatomprom JSC, Kazmunaygas JSC, KazdorNII JSC, at the Institute of Mechanics and Machine Science, at the Institute of Mathematics and Mathematical Modeling, etc. Master students have the opportunity to undergo an internship at leading engineering universities in Europe and Russia could under the academic mobility program.

During the study teaching is conducted by highly qualified teaching staff, including graduates of USA, Europe, Russia and other countries universities.

Graduates can choose variety career paths. They can either work in industry as practicing engineers or pursue doctoral studies in mechanical engineering or applied sciences. The best graduates have studied or are studying in the doctoral programs of AGH-University of Science and Technology (Poland), National University of Singapore, University of Pittsburgh (USA), University of Lorraine (France), Louisiana State University, KazNU and many other universities.

The Master's degree program "Engineering Mechanics and Modeling" is the second level of qualification of the three-level system of higher education, it lays the foundation for doctoral programs.

2. The purpose and objectives of the educational program

The purpose of the educational program "Engineering Mechanics and Modeling" is to train highly qualified mechanical engineers able to independently solve a wide range of engineering problems in mechanics, mechanical and power engineering using modern analytical, numerical and experimental methods, including mathematical and computer modeling.

Areas of professional activity of the graduate

profession	Job function A Scientific	Professional task A1: To investigate mass transfer and biochemical processes in porous media, develop efficient models of thermal and energy systems.	**Knowledge** Differential and integral calculus, Differential equations, Disciplines of the mechanical cycle, Computational fluid dynamics, Object-oriented programming, Fundamentals of flows in porous media and Applied problems, Applied Thermodynamics and Heat transfer, Introduction to Biomechanics.
			Skills Ability to perform high-performance computing, work at modern laboratory and research equipment. Ability to independently develop adequate physical, mathematical and numerical models of mechanical processes and phenomena. Ability to program in algorithmic languages and implement numerical models on computing resources. Ability to use mathematical and computer models of mechanical, heat and mass transfer processes for independent research of a wide range of engineering tasks and design of various hydraulic, thermal, energy systems.
			Standards of conduct: Self-learning and systemic thinking; IT competencies; creativity; cooperation with team members; ability to make decisions quickly, respond to changes of working conditions.
			Equipment and tools High-performance computing systems, specialized software and experimental installations for fluid mechanics (FM), mass transfer devices and thermal systems, energy, research equipment.
			Future trends The ability to use machine learning methods to study stochastic problems of mechanics. The ability to use quantum computing systems to solve resource-intensive problems of fluid mechanics.
		Professional task A2:	**Knowledge** Differential and Integral Calculus, Differential Equations, Disciplines of the mechanical cycle,

		Develop modern mechanical systems, mechanisms and mechanical devices, and robots.	Dynamic Systems Modeling, Computational Mechanics - CAD&CAE, Robot Mechanics and Control, Dynamic Systems: Vibration and Control.
			Skills Ability to work with modern laboratory and research equipment. The ability to independently develop and create new mechanisms and devices, including robots.
			Standards of conduct: Self-learning and systemic thinking; IT competencies; creativity; cooperation with team members; ability to make decisions quickly, respond to changes of working conditions.
			Equipment and tools Equipment for the development and research of mechanical systems, Special materials and structures, 3D printers.
			Future trends The ability to independently develop effective mechanical structures and autonomous mechanical systems and robots.
	Job function B Design and engineering	Professional task B1: Design and construction of the heat and mass transfer installations and biochemical reactors, converters and accumulators of renewable energy.	**Knowledge** Computational Fluid Dynamics, Turbulence: Principles and Application, Object-oriented programming, Machine learning and data analysis, Fundamentals of flow in porous media and Applied Problems, Introduction to Biomechanics, Applied Thermodynamics and Heat Transfer.
			Skills Ability to independently design and develop physical and mathematical models of mechanical and thermal phenomena and processes in heat and mass transfer installations, and biochemical reactors. Ability to independently conduct experimental and numerical studies of heat and mass transfer processes in complex and/or porous media, biochemical processes in reactors.
			Standards of conduct: Self-learning and systemic thinking; IT competencies; creativity; cooperation with team members; ability to make decisions quickly, respond to changes of working conditions.
			Equipment and tools High-performance computing systems and experimental installations for FM, specialized software for FM, for mass transfer devices and thermal systems, for energy, research equipment.
			Future trends

			The ability to independently design and develop of highly efficient heat and mass transfer installations and biochemical reactors, converters and accumulators of thermal energy.
		Professional task B2: Design and development of mechanisms and mechanical devices, autonomous mechanical systems and robots.	**Knowledge** Dynamic Systems Modeling, Computational Mechanics - CAD&CAE, Dynamic Systems: Vibration and Control, Robot Mechanics and Control.
			Skills The ability to work with high-tech laboratory and research equipment. The ability to independently design and develop new mechanisms and devices, including autonomous mechanisms and robots.
			Standards of conduct Self-learning and system thinking; IT competencies; creativity; cooperation with team members; ability to make decisions quickly, respond to changing working conditions.
			Equipment and tools 3D printers, computer systems, special materials and structures, equipment for the study of mechanical properties of materials, electronic measuring systems, electrical equipment.
			Future trends The ability to independently design and develop effective mechanical structures and autonomous mechanical systems and robots.
	Job function C production, technological, organizational, managerial	Professional task C1: Manage of production and technological processes in the extraction of metals by in-situ biochemical leaching, at the development of methods for storage and using solar heatenergy, the creation of robots and manipulators.	**Knowledge** Computational fluid dynamics. Object-oriented programming. Machine learning and data analysis. Fundamentals of flow in porous media and applied problems. Introduction to biomechanics. Method of in-situ leaching of metals. The methods of storage and usage of solar heat energy. Modeling of dynamic systems. Computational Mechanics - CAD&CAE. Dynamic systems: vibration and control. Robot mechanics and control.
			Skills The ability to develop models and computer program for technological tasks, the skills to study complex mechanical, physical and biochemical processes. Mastery of the methodology: system analysis; design and decision-making in complex and professional situations; methods of communication and coordination of points of view; design and presentation of analytical and project documentation.
			Standards of conduct

			Self-learning and systemic thinking, technological literacy, entrepreneurship, customer orientation, the ability to make decisions quickly, respond to changes in working conditions, the ability to allocate resources and manage your time.
			Equipment and tools Equipment for heat and mass transfer processes, renewable energy and robots.
			Future trends The ability to manage high-tech methods in the extraction of minerals, mechanical engineering and energy.

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

List of competencies

General competencies

- Proficiency in English for: searching for scientific and technical information; reviewing of the any sources of scientific and technical information on engineering mechanics; oral and written communication with a native speaker on a professional topic and in a real life situation.
- Mastery of critical systemic thinking, transdisciplinarity and cross-functionality.
- Possession of IT competencies, the ability to develop software using algorithmic languages.
- Mastery of skills: self-study; deepening of one's knowledge; being open to new information; systemic thinking and one's own judgment.
- The ability to be tolerant of another nationality, race, religion, culture; the ability to conduct an intercultural dialogue.
- Possession of communication skills, the ability to cooperate and work in a team.
- Ability to work in cases of high uncertainty and rapid change of task conditions; to work with consumer requests.
- Possession of a broad social, political and professional outlook; ability to use data from various sources and specialized literature, analyze and critically evaluate historical facts and events.
- Knowledge of the basics of entrepreneurship and business economics, readiness for social mobility.

Professional competencies

- Possession of fundamental knowledge in mathematics, mechanics, physics and scientific principles and the ability to use them in solving engineering problems.
- Ability to independently develop adequate physical and mathematical models of mechanical and thermal processes and phenomena.
- Ability to use mathematical and computer models of mechanical processes for independent research of a wide range of engineering problems of mechanics and design of various mechanical and energy systems.
- The ability to develop new mechanisms and devices, including autonomous mechanisms and robots.
- Ability to work with high-tech laboratory and research equipment.
- Knowledge of algorithmic languages and programming technology using object-oriented programming of mathematical and numerical models of physical processes and engineering problems.

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

Learning outcomes

LO 1 - to search and study scientific and technical information on engineering mechanics and be able to express in writing and orally their opinion on the topic of engineering mechanics in Kazakh (Russian) and English;
LO 2 - know the basics of management psychology and the basics of higher school pedagogy, possess teaching skills, know and critically analyze sources on the history and philosophy of science;
LO 3 - know the basics of continuum mechanics and turbulence theory, be able to use them in the study of engineering problems;
LO 4 - be able to analyze and model the dynamics of systems of particles and solids in three-dimensional motion, systems with one or more degrees of freedom;
LO 5 - know the methods of computational mechanics and computational fluid dynamics and be able to apply them to the study of problems in fluid mechanics, solids and engineering mechanics;
LO 6 - be able to develop codes in modern algorithmic programming languages, master the method of machine learning and data analysis, apply it to solve stochastic problems of engineering mechanics;
LO 7 - know the fundamentals of flow in porous media and be able to apply them in the extraction of metals by in-situ biochemical leaching;
LO 8 - know the basics of dynamic systems and be able to apply them to solve vibration and control problems, know the mechanics of contact and friction;
LO 9 - be able, using modern application software, to develop model and create various mechanical systems and devices, autonomous mechanisms and robots;
LO 10 - be able to analyze and optimize the design of thermal and refrigeration energy systems, including heat exchangers;
LO 11 - know the methods of obtaining, storing and using renewable energy, be able to design and create autonomous thermal sources and installations using solar thermal energy;

Learning strategy

The strategy of the educational program "Engineering Mechanics and 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-tech engineering, considering scientific trends in general and engineering mechanics in particular.

In the course of training, special attention is paid to the development by graduates of methods of mathematical, numerical and computer modeling, proven software for solving and researching a wide range of engineering problems. To achieve this goal, the structure of classes in almost all specialized disciplines includes both laboratory and practical classes, i.e. the theoretical knowledge of students is firmly anchored by the skills of their practical application.

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

Possession of fundamental knowledge in various fields of engineering mechanics and computer modeling skills will allow graduates to integrate relatively easily into the workflow of almost any industry, quickly enough to master a wide range of new technologies.

4. Passport of the educational program

educational program "7M07145 - Mechanical Engineering and Modeling"

4.1 General information

№	Title	
1	Code and classification of the field of education	7M07 Engineering, manufacturing and construction industries
2	Code and classification of the direction of training	7M071 Engineering and Engineering
3	Group of educational programs	M103 Mechanics and metalworking
4	Name of the educational program	7M07145 - Mechanical Engineering and Modeling
5	Short description	The educational program is aimed at training Masters able to solve independently a wide range of mechanical engineering problems by modern analytical, numerical and experimental methods, including mathematical and computer modeling. The curriculum of the educational program was developed based on the curricula of the Master's degree educational program "Mechanical Engineering" of world leader research and engineering universities, such as Stanford University, Massachusetts Institute of Technology – MIT, Georgia Institute of Technology, Nanyang Technological University (Singapore) and the Master's degree educational program "Mechanics and Mathematical modeling" of Bauman Moscow State Technical University and Peter the Great St. Petersburg Polytechnic University. The curriculum fully corresponds to modern trends in mechanical engineering, information technology and the demands of the economy and science of Kazakhstan. A feature of the program is the combination of engineering fundamentals with practical design skills. In the course of training, special attention is paid to the acquisition by graduates of in-depth knowledge in relevant areas of engineering mechanics, the ability to develop mathematical, physical and computer models of engineering problems and mastering the skills of independent research. The acquired knowledge as well as experience in programming and research using modern information technologies allow graduates to quickly integrate into the workflow of modern engineering and master a wide range of new technologies. Graduates will practice in such companies as Kazatomprom JSC, Kazmunaygas JSC, KazdorNII JSC, at the Institute of Mechanics and Machine Science, at the Institute of Mathematics and Mathematical Modeling, etc. Master students have the opportunity to undergo an internship at leading engineering universities in Europe and Russia

		could under the academic mobility program. During the study teaching is conducted by highly qualified teaching staff, including graduates of USA, Europe, Russia and other countries universities. Graduates can choose variety career paths. They can either work in industry as practicing engineers or pursue doctoral studies in mechanical engineering or applied sciences. The best graduates have studied or are studying in the doctoral programs of AGH-University of Science and Technology (Poland), National University of Singapore, University of Pittsburgh (USA), University of Lorraine (France), Louisiana State University, KazNU and many other universities. The Master's degree program "Engineering Mechanics and Modeling" is the second level of qualification of the three-level system of higher education, it lays the foundation for doctoral programs.
6	EP's Goal	The purpose of the educational program "Engineering Mechanics and Modeling" is to train highly qualified mechanical engineers able to independently solve a wide range of engineering problems in mechanics, mechanical and power engineering using modern analytical, numerical and experimental methods, including mathematical and computer modeling.
7	Type of EP	Master Degree Program
8	The level of the NRK	7M
9	Sectoral Qualifications Framework Level	7
10	Distinctive features of the EP	A feature of the program is the combination of engineering fundamentals with practical design skills. In the course of training, special attention is paid to the acquisition by graduates of in-depth knowledge in relevant areas of engineering mechanics, the ability to develop mathematical, physical and computer models of engineering problems and mastering the skills of independent research. The acquired knowledge as well as experience in programming and research using modern information technologies allow graduates to quickly integrate into the workflow of modern engineering and master a wide range of new technologies.
11	List of EP competencies	**General competencies** • Proficiency in English for: searching for scientific and technical information; reviewing of the any sources of scientific and technical information on engineering mechanics; oral and written communication with a native speaker on a professional topic and in a real-life situation. • Mastery of critical systemic thinking, transdisciplinarity and cross-functionality. • Possession of IT competencies, the ability to develop software using algorithmic languages. • Mastery of skills: self-study; deepening of one's knowledge; being open to new information; systemic thinking and one's own judgment.

		• The ability to be tolerant of another nationality, race, religion, culture; the ability to conduct an intercultural dialogue. • Possession of communication skills, the ability to cooperate and work in a team. • Ability to work in cases of high uncertainty and rapid change of task conditions; to work with consumer requests. • Possession of a broad social, political and professional outlook; ability to use data from various sources and specialized literature, analyze and critically evaluate historical facts and events. • Knowledge of the basics of entrepreneurship and business economics, readiness for social mobility. **Professional competencies** • Possession of fundamental knowledge in mathematics, mechanics, physics and scientific principles and the ability to use them in solving engineering problems. • Ability to independently develop adequate physical and mathematical models of mechanical and thermal processes and phenomena. • Ability to use mathematical and computer models of mechanical processes for independent research of a wide range of engineering problems of mechanics and design of various mechanical and energy systems. • The ability to develop new mechanisms and devices, including autonomous mechanisms and robots. • Ability to work with high-tech laboratory and research equipment. • Knowledge of algorithmic languages and programming technology using object-oriented programming of mathematical and numerical models of physical processes and engineering problems. • Knowledge of mathematical modeling and machine learning methods and computer modeling skills to work as a designer in mechanical engineering, energy, transport, chemical production. • Knowledge of methodology: system analysis; design and decision-making in complex and professional situations; methods of communication and coordination of points of view; design and presentation of analytical and project documentation.
12	Learning outcomes of the EP	LO 1 - to search and study scientific and technical information on engineering mechanics and be able to express in writing and orally their opinion on the topic of engineering mechanics in Kazakh (Russian) and English; LO 2 - know the basics of management psychology and the basics of higher school pedagogy, possess teaching skills, know and critically analyze sources on the history and philosophy of science; LO 3 - know the basics of continuum mechanics and turbulence theory, be able to use them in the study of engineering problems; LO 4 - be able to analyze and model the dynamics of systems of particles and solids in three-dimensional motion, systems with one or more degrees of freedom;

		LO 5 - know the methods of computational mechanics and computational fluid dynamics and be able to apply them to the study of problems in fluid mechanics, solids and engineering mechanics; LO 6 - be able to develop codes in modern algorithmic programming languages, master the method of machine learning and data analysis, apply it to solve stochastic problems of engineering mechanics; LO 7 - know the fundamentals of flow in porous media and be able to apply them in the extraction of metals by in-situ biochemical leaching; LO 8 - know the basics of dynamic systems and be able to apply them to solve vibration and control problems, know the mechanics of contact and friction; LO 9 - be able, using modern application software, to develop model and create various mechanical systems and devices, autonomous mechanisms and robots; LO 10 - be able to analyze and optimize the design of thermal and refrigeration energy systems, including heat exchangers; LO 11 - know the methods of obtaining, storing and using renewable energy, be able to design and create autonomous thermal sources and installations using solar thermal energy;
13	Form of training	Full - time
14	Duration of training	2 years
15	Volume of credits	120
16	Language	Kazakh, Russian, English
17	Academic degree awarded	Master of Engineering and Technology in the educational program "7M07145 - Engineering Mechanics and Modeling".
18	Developers and authors	assoc. prof. M.S. Tungatarova: assoc.prof. M.B. Izmambetov,

4.2. The relationship between the achievability of the formed learning outcomes according to the educational program and academic disciplines

№	Name of discipline	Short description of discipline	Cycle	Co mpo nent	Cre dits	The formed educational outcomes (codes)										
Learning outcomes of the EP						LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8	LO9	LO10	LO11
1	Foreign language (professional)	The course is designed for undergraduates of technical specialties to improve and develop foreign language communication skills in professional and academic fields. The course introduces students to the general principles of professional and academic intercultural oral and written communication using modern pedagogical technologies. Public discussions; interpret and present the results of scientific research in a foreign language.	BD	UC	3	✓										

2	History and philosophy of science	The subject of philosophy of science, dynamics of science, specifics 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-non-classical science, philosophy of mathematics, physics, engineering and technology, specifics of engineering sciences, ethics of science, social and moral responsibility of a scientist and engineer.	BD	UC	3		✓									
3	Higher school pedagogy	Undergraduates will master the methodological and theoretical foundations of higher school pedagogy, plan and organize the processes of teaching and upbringing, master the communicative technologies of subject-subject interaction between a teacher and a master in the educational process of a university.	BD	UC	3		✓									

4	Psychology of management	The discipline studies the modern role and content of psychological aspects in managerial activity. The improvement of the psychological literacy of the student in the process of implementing professional activities is considered. Self-improvement in the field of psychology and studying the composition and structure of management activities, both at the local level and abroad. The psychological feature of modern managers is considered.	BD	UC	3		✓									
5	Dynamics of mechanical systems	Goal: Motion analysis and modeling of dynamics of systems of particles and solids in three-dimensional motion. Summary of the discipline. Kinematics of solids: general relations, Schall's theorem, Euler angles. Newton-Euler kinetics of a solid: fundamental principles of motion and energy of a solid. Analytical mechanics: generalized coordinates and degrees of freedom, virtual	BD	EC	5				✓							

		displacements, generalized forces, Hamilton's principle, Lagrange equations. Applications: computational methods, communications, Coulomb friction, rolling, gyroscopic systems.														
6	Intellectual property and research	Purpose: the goal is to train specialists who can effectively manage rights to the results of intellectual activity in the field of science, as well as ensure their legal protection and commercialization. Contents: analysis of legal protection of research and development results, methods of commercialization of scientific inventions, ethical and legal aspects of scientific activity in the context of IP.	BD	EC	5	✓										
7	Methods for calculating turbulent flows	Purpose: to teach students the methods of calculating turbulent flows encountered in engineering problems. Summary Laminar and turbulent flows. Algebraic models for calculating turbulent flows. One and	BD	EC	5			✓								

		two-parameter models. Models based on Reynolds stresses. Methods for calculating large vortices.														
8	Contact mechanics and friction	Goal: To introduce students to the mechanics of surface contact in rolling and sliding bearings and with elements of lubrication theory. Summary: The Hertz contact. Non-Herzov elastic contact. Contact with rough surfaces. Normal contact of inelastic solids. Wear mechanisms. Tangential load and sliding contact. Rolling contact and rolling friction. Fundamentals of lubrication theory and its applications.	BD	EC	5								✓			
9	Fundamentals of continuum mechanics	Goal: To provide knowledge of fundamental, unifying concepts of continuum mechanics as a core course for undergraduates in the field of engineering mechanics. Summary Fundamentals of the theory of the stress-strain state of bodies, fundamentals of the	BD	EC	5			✓								

		theory of Newtonian fluids, laws of thermodynamics of a continuous medium.														
10	Sustainable development strategies	The goal is to develop deep knowledge and competencies in the development and implementation of sustainable development strategies at various levels. The content covers a wide range of topics, ranging from global environmental challenges such as climate change, biodiversity loss and natural resource depletion, to socio-economic aspects including inequality, health and education.	BD	EC	5		✓									
11	Turbulent flows	Objective: To provide engineers with guidance on working with turbulent flow using as few mathematical equations as possible. Summary Turbulence of the liquid. Characteristics of some important turbulent flows. Averaged by Reynolds, the closure problem. Models based on the Boussinesq approximation. k – e and other models of two	BD	EC	5			✓								

		equations. Direct numerical simulation and simulation of large vortices.														
12	The phenomenon of mass transfer and transfer in a continuous medium	Goal: To acquaint students with the theory of the phenomenon of mass transfer and transfer in a continuous medium and the practice of modeling and analysis, Summary Introduction and basic concepts Basic models, conservation equations, and closure relations. Heat transfer at boiling Basic concepts, nucleation phenomena and the boiling curve. Forced-convective boiling. Condensate, basic concepts. Condensation in a calm environment. Condensation in a two-phase flow. Introduction to aerosol transfer. Mechanisms of aerosol transport	BD	EC	5										✓	
13	Computational fluid dynamics	Purpose: teaching methods of numerical solution of fluid flow prob-lems arising in various engineering devices. The course gives students the experience of numerical solution of vis-	PD	UC	5					✓						

		cous and inviscid fluid flows. Students will receive the following: • knowledge of many different numerical methods, their behavior, ad-vantages and disadvantages; • experience of numerical solution of the fluid flow problem. Summary Numerical methods for solving nonstationary Navier-Stokes equations, including theory, implementation and applications. • Overview of the Navier-Stokes equations. Classification of PDE. • Finite difference method. Derivation of the main difference formulas, approximation, stability and convergence of the method. • Difference schemes for solving hyperbolic, parabolic and elliptic problems. • Finite volume method, method derivation; approximation, stability and convergence; applications. Spectral methods. Method derivation; approximation,														

		stability and convergence and applications.														
14	Computational Mechanics - CAD&CAE	Purpose: to teach students to apply geometric modeling methods using commercial CAD systems. Summary CAD fundamentals, including geometric and solid-state modeling, parametric representations, elements and human-machine interaction. Applications for design, analysis and production.	PD	UC	5					✓						
15	Dynamic systems: vibration and control	Objectives: Modeling, analysis and measurement of mechanical dynamical systems, systems with one and several degrees of freedom. Summary Closed-form ODE solutions that determine the behavior of systems with one or more degrees of freedom. Stability, forcing, resonance and control system design. Modeling and analysis of free and forced oscillations of systems with concentrated elements with one and several degrees of freedom.	PD	UC	5								✓			

16	Artificial intelligence in engineering	Purpose: to familiarize with the basics of artificial intelligence and its application in engineering problems. Summary Introduction to artificial intelligence. Neural networks. Structure and hyperparameters of neural networks. Formation and normalization of the input layer. Activation function of hidden layers. Formation of the output layer. The function is lost. Application of optimization methods for training artificial intelligence. Forecasting and assessment. Artificial intelligence and numerical modeling. Application of artificial intelligence to solve problems of underground hydrodynamics. Assessment of forecasting accuracy.	PD	UC	4										✓	

17	Machine learning and data analysis	Purpose: to familiarize with the basics of machine learning and its application in stochastic engineering problems and data analysis. Summary Linear classifier and stochastic gradient. Neural networks: gradient optimization methods. Metric methods of classification and regression. The method of support vectors. Multidimensional linear regression. Nonlinear regression. Model selection criteria and feature selection methods. Logical classification methods. Deep neural networks. Neural networks with unsupervised learning.	PD	UC	5						✓					
18	Object-oriented programming	Purpose: to give students an idea of the basic principles of object-oriented programming (OOP) in C++ and C#. Summary Basic concepts. Classification of subspecies of OOP. Definition of OOP and its basic concepts. Implementation features. Program design in	PD	UC	5						✓					

		general. Various OOP methodologies. Component programming. Prototype programming. Class-oriented programming														
19	Applications of thermodynamics	Purpose: To teach students to apply the basics of the first and second laws of classical thermodynamics to the analysis and optimization of the design of heating and refrigeration energy systems, including heat exchangers. Summary The first and second laws of thermodynamics. Application to the analysis and optimization of the design of: thermal and refrigeration power systems; heat exchangers and combustion processes. • Power generation cycles • Heat pump cycles (cooling) • Optimization of the heat exchanger in cycles • Studies of thermo-economic models.	PD	UC	5										✓	
20	Robotics	Purpose: To give an idea of the mathematical tools and algorithms included in the planning and control of movement and	PD	UC	5									✓		

		force, as well as to teach the skills of using these methods. Summary Analysis and design of robotic systems, including weapons and vehicles. Kinematics and dynamics. Algorithms for describing, planning, controlling and controlling the force of movement.														
21	Renewable energy systems	Purpose: formation of knowledge in the field of renewable energy sources and training in the skills of their use.. Summary The volume of reserves of traditional energy carriers. Nuclear energy and the greenhouse effect. Solar radiation. Wind energy. Water energy. Geothermy. Use of biomass. Hydrogen production, fuel cells and methanization.	PD	UC	5											✓
22	Filtration theory and applied problems	Purpose: to familiarize with the basics of filtration theory and its appli-cations in the technology of metal extraction by underground borehole leaching. Summary Basic concepts and equations of filtration theory (TF). The laws of conservation of mass and	PD	UC	5						✓					

		momentum during filtration in a porous medium, Darcy's law. Derivation of differential filtration equations. Filtration of incompressible fluid in a non-deformable porous medium. Filtration taking into account the weak compressibility of the liquid and the porous skeleton. Applications of TF in the technology of metal extraction by underground borehole leaching.														

4.4 Information about disciplines

№	Nameofthedis cipline	Brief description of the discipline	Num berof credit s	Emerging competencies
CYCLE OF BASIC DISCIPLINES (BD)				
M-1. Basic Training module (university component)				
1.	English language (professiona l)	**Goal:** The course is designed for undergraduates of technical specialties to improve and develop foreign language communication skills in professional and academic fields. **Summary** The course introduces students to the general principles of professional and academic intercultural oral and written communication using modern pedagogical technologies. The course ends with a final exam. Undergraduates also need to study independently (MIS).	5	Ability: Analyze and understand ideological problems from scientific positions, independently master cultural riches, think logically correctly and argumentatively and correctly build oral and written speech. Freely use the state language and a foreign language as a means of business communication and in the field of professional activity
2.	Psychology of managemen t	**Goal:** The discipline studies the modern role and content of psychological aspects in managerial activity. **Summary** The improvement of the psychological literacy of the student in the process of implementing professional activities is considered. Self-improvement in the field of psychology and studying the composition and structure of management activities, both at the local level and abroad. The psychological feature of modern managers is considered.	3	Ability: Analyze and understand ideological problems from scientific positions, independently master cultural riches, think logically correctly and argumentatively and correctly build oral and written speech. Freely use the state language and a foreign language as a means of business communication and in the field of professional activity
3.	History and philosophy of science	**Goal:** The subject of philosophy of science, dynamics of science, specifics 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-non-classical science, philosophy of mathematics, physics, engineering and technology, specifics of engineering sciences, ethics of science, social and moral responsibility of a scientist and engineer.	3	Ability: Analyze and understand ideological problems from scientific positions, independently master cultural riches, think logically correctly and argumentatively and correctly build oral and written speech. Freely use the state language and a foreign language as a means of business communication and in the field of professional activity
4.	Higher school pedagogy	**Goal:** The course is intended for undergraduates of the scientific and pedagogical magistracy of all specialties. **Summary** As part of the course, undergraduates will master the methodological and theoretical foundations of higher school pedagogy, learn how to use modern pedagogical technologies, plan and organize learning and education processes, master the communicative technologies of subject-subject interaction between a teacher and a graduate student in the educational process of a university. Also, undergraduates study human resource	5	Ability: Analyze and understand ideological problems from scientific positions, independently master cultural riches, think logically correctly and argumentatively and correctly build oral and written speech. Freely use the state language and a foreign language as a means of business communication and

		management in educational organizations (using the example of a higher school).		in the field of professional activity
Component of choice				
1.	Fundamentals of continuum mechanics	**Goal:** To provide knowledge of fundamental, unifying concepts of continuum mechanics as a core course for undergraduates in the field of engineering mechanics. **Summary** Introduction to the basic, unifying concepts of continuum mechanics. • Determination of stress, main stresses, deviatory and hydrostatic stress. • The first and second laws of continuum thermodynamics, boundary conditions. • Fundamentals of elastic behavior of solids, variational principles. • Fundamentals of fluids, Navier-Stokes equations, laminar and turbulent flows.	5	Ability: Know the basic unifying concepts of continuum mechanics. Know models and methods of continuum mechanics (CM). Be able to analyze the stress-strain state of bodies. Be able to apply the laws of continuum thermodynamics to solve practical problems.
2.	The phenomenon of mass transfer and transport in a continuous medium	**Goal:** To acquaint students with the theory of the phenomenon of mass transfer and transport in a continuous medium and the practice of modeling and analysis **Summary** Introduction and basic concepts Basic models, conservation laws and closure relations. Heat transfer at boiling Basic concepts, nucleation phenomena and the boiling curve. Forced-convective boiling. Condensate, basic concepts. Condensation in a calm environment. Condensation in a two-phase flow. Introduction to aerosol transfer. Mechanisms of aerosol transport	5	Know the basic concepts of the theory of mass and heat transport. Know models and methods for solving mass and heat transport problems. Be able to analyze mass and heat transport problems and be able to apply their calculation methods to solve practical problems.
3.	Dynamics of mechanical systems	**Goal:** Motion analysis and modeling of dynamics of systems of particles and solids in three-dimensional motion. **Summary of the discipline.** Kinematics of solids: general relations, Chasles' theorem, Euler angles. Newton-Euler kinetics of a solid: fundamental principles of motion and energy of a solid. Analytical mechanics: generalized coordinates and degrees of freedom, virtual displacements, generalized forces, Hamilton's principle, Lagrange equations. Applications: computational methods, communications, Coulomb friction, rolling, gyroscopic systems.	5	Be able to: choose suitable geometric modeling methods for a given mechanical design situation; apply geometric modeling methods using commercial CAD systems; to build a modifiable CAD model of both components and assemblies and use these models in solving design problems; apply geometric tolerances to these models and perform simple tolerance analysis; analyze the relevance of virtual and physical rapid prototypes in design situations based on an understanding of the information used in their creation.
4.	Mechanics of contact and friction	**Goal:** To acquaint students with the mechanics of surface contact in rolling and sliding bearings and with the elements of lubrication theory. **Summary of the discipline.** The Hertz contact. Non-Hertz elastic contact. Contact with rough surfaces. Normal contact of inelastic solids. Wear mechanisms. Tangential load and sliding contact. Rolling contact and rolling friction. Fundamentals of lubrication theory and its applications..	5	Know the mechanics of surface contact of solids Be able to analyze tribological interactions in rolling and sliding bearings. Know the basics of lubrication theory and its applications.

5.	Modeling and control of motion systems	**Goal:** Motion systems including mechanical, fluid and electrical components are analyzed, modeled and controlled.Students will use controllers for dynamic and robotic systems in the laboratory. **Summary** 1. System dynamics and control; continuous control systems. 2. Computer-controlled systems; discrete-time control systems; Z transformation. 3. Feedback control systems; linearity and nonlinearity; drives; sensors; modeling; PID tuning. 4. User interfaces; work; medical equipment; mobile equipment; transport; production. Laboratory: 1. LabVIEW, MATLAB SIMULINK and microcontrollers. 2. Precision control systems. 3. Control/configuration of robotic complexes. 4. Projectmanagementsystem.	5	Know the basic concepts and characteristics of porous media. Possess the appropriate theory, formulations and methodologies for describing flows in porous media. Be able to build a model to describe processes in a porous medium. Apply the appropriate solution method using numerical modeling for a wide range of tasks.
6.	Modeling of dynamics of systems of particles and solids	**Goal:** Motion analysis and modeling of dynamics of systems of particles and solids in three-dimensional motion. **Summary of the discipline.** • Overview of kinematics and dynamics of particles: position, velocity, acceleration, Newton's laws, principles of energy and momentum. Relative motion: rotation transformations, finite rotations, angular velocity and acceleration. • Kinematics of solids: general relations, Schall's theorem, Euler angles, relationships and conditions of connection, engagement, rolling. • Newton-Euler kinetics of a solid body: fundamental principles of motion and energy of a solid body, equations of three-dimensional motion, Euler equations, systems of solids. • Analytical mechanics: generalized coordinates and degrees of freedom, finite and differential connections, virtual displacements, generalized forces, Hamilton's principle, Lagrange equations. • Applications: computational methods, communications, Coulomb friction, rolling, gyroscopic systems.	5	Ability: To master the theory, formulations and methodologies for modeling, analyzing and measuring mechanical dynamical systems for their vibration response characteristics using both accurate and approximate methods. The ability to model and analyze free and forced oscillations of systems with concentrated elements with one or more degrees of freedom; continuous oscillatory systems, including approximate solution methods.
7.	Turbulent flows	**Goal:** provide engineers with guidance on working with turbulent flow using as few mathematical equations as possible. **Summary** Turbulence of the liquid. Characteristics of some important turbulent flows. Equations Averaged by Reynolds, the closure problem. Models based on the Boussinesq approximation. k – e and other models of two equations. Direct numerical simulation and simulation of large vortices.	5	Ability: know the engineering aspects of turbulent flows; know important practical situations in which turbulent flows occur; possess methods of solving problems of turbulent convective heat transfer, including forced and free convection.
8.	Methods for calculating turbulent flows	**Purpose:** to teach students the methods of calculating turbulent flows encountered in engineering problems. **Summary** Laminar and turbulent flows. Algebraic models for calculating turbulent flows. One and two-parameter models. Models based on Reynolds stresses. Methods for calculating large eddies.	5	Ability: know the basic models and methods for calculating turbulent flows; be able to apply methods of calculating turbulent flows to solve engineering problems.
CYCLE OF PROFILE DISCIPLINES (PD)				
M-2. Profile training module (university component and optional component)				
1.	Computational fluid dynamics	**Purpose:** teaching methods of numerical solution of fluid flow problems arising in various engineering devices. The course gives students the experience of numerical solution of viscous and inviscid fluid flows. Students will receive the following: • knowledge of many different numerical methods, their behavior,	5	**Be able to:** choose a method of numerical solution of a specific problem of fluid mechanics, set boundary conditions;

		advantages and disadvantages; • experience of numerical solution of the fluid flow problem. **Summary** Numerical methods for solving nonstationary Navier-Stokes equations, including theory, implementation and applications. • Overview of the Navier-Stokes equations. Classification of PDE. • Finite difference method. Derivation of the main difference formulas, approximation, stability and convergence of the method. • Difference schemes for solving hyperbolic, parabolic and elliptic problems. • Finite volume method, method derivation; approximation, stability and convergence; applications. • Spectral methods. Method derivation; approximation, stability and convergence and applications.		build a numerical model of the problem; develop a computer program and perform calculations; analyze the results and validate the model, if necessary, adjust the numerical and/or computer models.
2.	Object-oriented programming	**Purpose:** to give students an idea of the basic principles of object-oriented programming (OOP) in C++ and C#. **Summary** Basic concepts. Classification of subspecies of OOP. Definition of OOP and its basic concepts. Implementation features. Program design in general. Various OOP methodologies. Component programming. Prototype programming. Class-oriented programming.	5	**To know:**modern methods and tools for the development of algorithms and programs; the principles of object-oriented analysis and design, the basics of an object-oriented approach to programming. **Be able to:** apply knowledge in solving complex applied problems; carry out object decomposition of the subject area. **Possess:** methods of developing and modifying computer programs using an object-oriented approach
3.	Computational Mechanics - CAD&CAE	**Goal:** After completing this course, the student should be able to: • choose suitable geometric modeling methods for this mechanical design situation, • apply geometric modeling methods using commercial CAD systems, • build a modifiable CAD model of both components and assemblies and use these models in solving design tasks, • apply geometric tolerances to these models and perform simple tolerance analysis, • analyze the relevance of virtual and physical rapid prototypes in project situations based on an understanding of the information used in their creation. **Summary** CAD fundamentals, including geometric and solid-state modeling, parametric representations, elements and human-machine interaction. Applicationsfordesign, analysisandproduction.	5	**Be able to:** choose suitable geometric modeling methods for a given mechanical design situation; apply geometric modeling methods using commercial CAD systems; build a modifiable CAD model of both components and assemblies and use these models in solving design problems; apply geometric tolerances to these models and perform simple tolerance analysis; analyze the relevance of virtual and physical rapid prototypes in project situations based on an understanding of the information used in their creation.
4.	Machine learning and data analysis	**Purpose:** to familiarize with the basics of machine learning and its application in stochastic engineering problems and data analysis. **Summary** Linear classifier and stochastic gradient. Neural networks: gradient optimization methods. Metric methods of classification and regression. The method of support vectors. Multidimensional linear regression. Nonlinear regression. Model selection criteria and feature selection methods. Logical classification methods. Deep neural networks. Neural networks with unsupervised learning.	5	**Be able to:** Choose the appropriate type of classifier depending on the task being solved; select a set of features for classification and perform data processing; apply algorithms for constructing and training a classifier based on a sample; analyze data, pre-process and clean data; visualize data,

				including using dimensionality reduction methods.
5.	Filtration theory and applied problems	**Purpose:** to familiarize with the basics of filtration theory and its applications in the technology of metal extraction by in-situ leaching. **Summary** Basic concepts and equations of flows in porous media. The laws of mass and momentum conservation for flows in porous medium, Darcy's law. Derivation of differential filtration equations. Flow of incompressible fluid in a non-deformable porous medium. Filtration taking into account the weak compressibility of the liquid and the porous media. Applications of theory for the technology of metal extraction by in-situ leaching.		**Know the basic** concepts and characteristics of porous media. Possess the appropriate theory, formulations and methodologies for describing flows in porous media. Be able to build a model to describe processes in a porous medium. Apply the appropriate solution method using numerical modeling for a wide range of tasks.
6.	Dynamic systems: vibration and control	**Objectives:** Modeling, analysis and measurement of mechanical dynamic systems. Systems with one and several degrees of freedom, as well as continuous systems, are analyzed for their vibration response characteristics using both exact and approximate methods. **Summary** Solutions of ordinary differential equations in closed form that determine the behavior of systems with one or more degrees of freedom. Stability, forcing, resonance and control system design. Introduction to modeling and analysis of oscillatory response for discrete and continuous mechanical and structural systems. Modeling and analysis of free and forced oscillations of systems with concentrated elements with one and several degrees of freedom. Modeling and analysis of continuous oscillatory systems, including approximate solution methods.	5	Ability: To master the theory, formulations and methodologies for modeling, analyzing and measuring mechanical dynamical systems for their vibration response characteristics using both accurate and approximate methods. The ability to model and analyze free and forced oscillations of systems with concentrated elements with one or more degrees of freedom; continuous oscillatory systems, including approximate solution methods.
7.	Robotics	**Goal:**To give an idea of the mathematical tools and algorithms included in the planning and control of movement and force, as well as to teach the skills of using these methods. **Summary** Analysis and design of robotic systems, including weapons and vehicles. Kinematics and dynamics. Algorithms for describing, planning, controlling and controlling the force of movement.		Skill is an interdisciplinary field of science and technology that deals with the design, creation and use of robots. Robotics-related skills cover a wide range of knowledge and skills
8.	Applications of thermodynamics	**Goal:**To teach students to apply the basics of the first and second laws of classical thermodynamics to the analysis and optimization of the design of energy and refrigeration energy systems, including heat exchangers and combustion processes. **Summary** The first and second laws of thermodynamics.Application to the analysis and optimization of the design of: thermal and refrigeration power systems; heat exchangers and combustion processes. • Chemically active systems • The effectiveness of the Second Law system • Power generation cycles • Heat pump cycles (cooling) • Optimization of the heat exchanger in cycles • Studies of thermo-economic models.	5	Ability to use mathematical tools to analyze the kinematics and dynamics of robotic systems; develop and apply motion planning and force control algorithms to solve engineering problems; possess programming methods for trajectory planning and motion control algorithms, as well as design control systems for robotic devices considering dynamic and kinematic characteristics. The use of modern tools for simulation of robotic systems and transport the ability to independently conduct research and data analysis in

				the field of robotics and transport systems.
9.	Renewable energy systems	**Purpose:** formation of knowledge in the field of renewable energy sources and training in the skills of their applications/ **Summary of the discipline.** The volume of reserves of traditional energy sources. Nuclear energy and the greenhouse effect. Solar radiation. Wind energy. Water energy. Geothermal energy. Use of biomass. Hydrogen production, fuel cells and methanization.	5	The ability to analyze the potential and reserves of traditional and renewable energy sources; apply environmental impact assessment methods, including the greenhouse effect; use knowledge about solar, wind, water and geothermal energy to design systems; develop solutions for the use of biomass, hydrogen and fuel cell production; evaluate and optimize energy installations based on alternative sources.
10.	Artificial intelligence in engineering	**Goal**: To develop students' knowledge and skills in applying artificial intelligence (AI) methods and technologies to solve engineering problems, automate processes and optimize design. **Summary of the discipline.**: The basics of AI and machine learning. Application of neural networks and deep learning algorithms for engineering analysis and forecasting. Big data processing methods, intelligent management systems and optimization. Development and implementation of AI solutions for automation of engineering processes. Examples of the use of AI in robotics, energy, construction and manufacturing.	5	The ability to analyze and apply AI methods to solve engineering problems; develop and configure neural networks and machine learning models; use deep learning algorithms for data processing and forecasting; apply AI solutions for automation and optimization of engineering processes; work with big data analysis and intelligent management tools; evaluate the effectiveness of AI implementation in various engineering projects and industries.

5. Curriculum of educational program

OF EDUCATIONAL PROGRAM for enrollment for 2024-2025 academic year
Educational program 7M07145– "Mechanical Engineering and Modeling"
Group of educational programs M103 – "Mechanics and matalworking"

Form of study: full-time **Duration of study: 2 year** **Academic degree: Master of Technical Sciences**

Discipline code	Name of disciplines	Cycle	Total amount in credits	Total hours	Classroom amount lec/lab/pr	SIS (including TSIS) in hours	Form of control	Allocation of face-to-face training based on courses and semesters			
								I course		2 course	
								1 sem	2 semr	3 sem	4 sem
CYCLE OF BASIC DISCIPLINES (BD)											
M-1. Module of basic training (university component)											
LNG213	Foreign language (professional)	BD UC	3	90	0/0/2	60	E	3			
HUM214	Management Psychology	BD UC	3	90	1/0/1	60	E	3			
HUM212	History and philosophy of science	BD UC	3	90	1/0/1	60	E		3		
HUM213	Higher school pedagogy	BD UC	3	90	1/0/1	60	E		3		
component of choice											
GEN202	Fundamentals of continuum mechanics	BD CCH	5	150	1/0/2	105	E	5			
GEN220	The phenomenon of mass transfer and transfer in a continuous medium										
MNG781	Intellectual property and research	BD CCH	5	150	2/0/1	105	E	5			
GEN209	Dynamics of mechanical systems				1/0/2						
GEN221	Contact mechanics and friction										
MNG782	Sustainable development strategies	BD CCH	5	150	2/0/1	105	E			5	

GEN210	Turbulent currents				1/0/2						
GEN222	Methods for calculating turbulent flows										
CYCLE OF PROFILE DISCIPLINES (PD)											
M-2. Module of professional activity (university component, component of choice)											
GEN211	Computational fluid dynamics	PD UC	5	150	1/2/0	105	E	5			
GEN212	Object-oriented programming	PD UC	5	150	1/1/1	105	E	5			
GEN213	Computational Mechanics - CAD&CAE	PD UC	5	150	1/2/0	105	E		5		
GEN214	Machine learning and data analysis	PD UC	5	150	1/1/1	105	E		5		
GEN215	Filtration theory and applied problems	PD UC	5	150	1/1/1	105	E		5		
GEN216	Dynamic systems: vibration and control	PD UC	5	150	1/1/1	105	E		5		
GEN217	Robotics	PD UC	5	150	1/1/1	105	E			5	
GEN218	Applications of thermodynamics	PD UC	5	150	1/1/1	105	E			5	
GEN219	Renewable energy systems	PD UC	5	150	1/0/2	105	E			5	
GEN223	Artificial intelligence in engineering	PD UC	4	120	2/0/1	75	E				4
M-3. Practice-oriented module											
AAP273	Pedagogical practice	BD CCH	8							**8**	
AAP256	Research practice	PD, UC	4								4
M-4. Experimental research module											
AAP268	Research work of a master's student, including internship and completion of a master's thesis	RWMS UC	4					4			

AAP268	Research work of a master's student, including internship and completion of a master's thesis	RWMS UC	4						4		
AAP251	Research work of a master's student, including internship and completion of a master's thesis	RWMS UC	2							2	
AAP255	Research work of a master's student, including internship and completion of a master's thesis	RWMS UC	14								14
M-5. Module of final attestation											
ECA212	Preparation and defense of a master's thesis	FA	8								8
	Total based on UNIVERSITY:							30	30	30	30
								60		**60**	

Number of credits for the entire period of study					
Cycle code	**Cycles of disciplines**	**Credits**			
			university	**component of choice (CCH)**	**Total**
BD	Cycle of basic disciplines		20	15	35
PD	Cycle of profile disciplines		53	0	53
	Total for theoretical training:	***0***	***73***	***15***	***88***
	RWMS				***24***
FA	Final attestation	8			8
	TOTAL:	**8**	**73**	**15**	**120**