NJSC «K.I. Satbayev Kazakh National Research Technical University»
Institute of Information and Telecommunication Technologies
Department of Mathematics

CURRICULUM PROGRAM

«Cybernetics and artificial intelligence»
PhD

Based on invalidated classification of specialty:
«6D070500 – Mathematical and Computer Modeling»

1-st edition
in correspondence with the national standard of education of the Republic of Kazakhstan 2018

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The program is compiled and signed by

Approved at the Session of Educational and Methodological Board of NJSC «K.I. Satbayev Kazakh National Research Technical University».
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Qualification:
The 8D level of the technologies of information and communication, «8D06»

Professional competence:

- ability to apply the perspective methods of study and using solutions of professional tasks, which based on the world tendencies of the development of mathematics, computer engineering and information technologies;
- ability to develop conceptual and theoretical models of solving scientific problems and applied tasks;
- ability to plan scientific and research activity, to analyze risks and to manage projects.

SHORT DESCRIPTION OF THE PROGRAM

The educational program belongs to engineering specialization.

It is aimed at providing basis and professional courses with due competence to students.

The tasks and content of the program are described in Section 7 of the document: «Description of the courses».

The specialization is created with the focus on training competitive professionals in computer science and information technologies, which will possess the valuable knowledge in such future technologies as artificial intelligence and hence will be distinguished on the international IT market.

Students will study the main methods of artificial intelligence on simple handy problems and get the mathematical foundation of machine learning and artificial intelligence. The main idea of this program consists in modelling the intellectual activity by means of computers. Completing the program, students will have the knowledge of working machine learning algorithms and will be able to implement these skills in solution of various (theoretical or applied) problems. After successful completion of the program the students will be graduated the «bachelor» degree.

The education process presumes an active research work, participation in research projects supervised by leading specialists in priority scientific areas, and internship in foreign high-profile scientific and educational institutions. Some classes will get lectures by invited professors from Germany, France, Slovenia, etc.

For students to acquire competitive skills, the program includes innovative courses that cover all necessary areas from Mathematics, Data Science, Data Engineering and Quantitative Analysis (in Python and R languages).

The «Cybernetics and artificial intelligence» program includes such innovative disciplines as:

- Parallel computing;
- Artificial neural networks and their applications;
- Machine learning;
- Quantum programming for data analysis.

PhD students of the program will acquire such skills as:

- ability to formulate and build models
- ability to create complicated motion effects to visualize the results of their own projects
- ability to make effective decisions for project management

The graduated student must

be acquainted with:

- the object under study
- the modern methods and programming tools for investigating and modelling various processes

know:

- theoretical and practical foundations for mathematical modelling of physical, medical, chemical and biological processes
- high level programming languages, visual programming tools, and modelling languages
- computers, system administration, computer networks, operation systems, applied programs

be able to:

- analyze the object under study
- create a mathematical model
- apply mathematical tools for problems' solution
- optimally utilize computers
- develop and create data bases
- write computer programs

The graduates of the program will have the knowledge and skills to realize themselves in various professional activities like:

- scientific and educational areas
- mathematical and computer modelling, and artificial intelligence
- computer programming
- research, technical experiments and analyses, experimental developments of natural sciences and engineering
- state management
- business area as a top management
- research institutes

The students have the opportunity to do their internship and work in all banks of Kazakhstan, KazMunaiGaz and other oil and gas companies, Institute of mathematics and mathematical modelling, Institute of information and computer technologies, "National scientific laboratory of information and space technologies" and, also, in the School of Mathematics and cybernetics of Satbayev University.

Furthermore, this program provides the exchange program in liaison with foreign universities such as Lublin University of Technology (Poland), the University of Bielsko-Biala (Poland), University of L'Aquila (Italy), New York University, Girne American University (island of Cyprus), the University of Windsor (Canada), etc.

PASSPORT OF THE EDUCATIONAL PROGRAM

The scope and content of the program

The curriculum program is oriented on the fundamental educational, methodological and research preparation.

The content of the curriculum program is established by the university.

The main indicator of an accomplishment of the educational program is the presence of enough academic hours, which cannot be more than 180.

The PhD curriculum program focuses on both directions:

1. scientifically pedagogical direction (at least three years)
2. profile direction (at least three years)

The content of the curriculum program consists of:

1. the theoretical learning , including the based and special disciplines
2. internships and scientific study placement
3. scientifically research work
4. final attestation

The content of the "Cybernetics and Artificial Intelligence" program:

Educational program tasks:

1. The purposes of the curriculum program

The curriculum programme involves issues about fundamentals of the artificial intelligence system, features of its organization, functionality, life cycles and directions. Moreover, the programme helps to students to develop their competences in the project processes and professional activity in the contemporary intellectual systems.

Therefore, the curriculum programme focuses on the preparation of highly qualified specialists, who is capable to develop both computer and mathematical models for different applications according on the development of digital economy. The program has a practice-oriented base using the modern laboratory "Sigma LABS" at the School of mathematics and cybernetics.

Nowadays, the artificial intelligence modelling has two main approaches:

1. Machine intelligence, based on the strong task of the result of functioning;
2. Artificial intelligence, focusing on the modeling of the internal structure of the system.

The approaches division relates with the existence of two points of view on the question of how to build artificial intelligence systems.

The one side represents, that the most important fact is the result. It means, that the main idea focuses on the concurrence of artificial and natural intelligent systems, but not on the process of formulation of behavior through the internal mechanisms.

Another point of view is the consideration that the basis of the construction of artificial intelligence involves mechanisms of natural thinking and the analysis of data, which characterize the rational human behavior. Thus, this process is realized by the modeling using the technical principles and the specifics of the functionality of biological objects.

Therefore, the first direction studies the product of human intellectual activity and its structure, and focuses on the realization of the product through the instruments of modern technics. That modelling of the machine intelligence systems is achieved by using the laws of formal logic, set theory, graphs, semantic networks, and other scientific advances in the field of discrete computing. The main results are in the creation of expert systems, natural language parsing systems and the simplest control systems of the <stimulus-reaction> form. Therefore, the success of the first direction of the artificial intelligence is closely related with the development of computer capabilities and programming. So that, it involves the complex of scientific and technical research as computer sciences.

The second direction of artificial intelligence considers data of the neurophysiological and psychological mechanisms of intellectual activity, generally, as a rational human behavior. The direction represents mechanisms through the various technical devices, in case that the "behavior" of such devices concurs with a human behavior according to the certain limits. The development of this area is closely related to the studying of human sciences. It includes wider spectrum of rational human activity comparing with the machine intelligence. The artificial intelligence systems are based on the mathematical interpretation of the activity of the human brain nervous system. Thus, they are realized as neural networks, based neural element as an analog of a neuron.

2. Entry requirements

The PhD programme is allowed to persons who have a "Master" degree and working experience at least 1 (one) year or, who have completed residency studying.

Enrollment is carried out by the special commissions of the university and scientific organizations according on the results of the entrance exam of PhD educational program. Also, PhD applicants should have the certificate with the level of the foreign language in accordance with the common European competencies (standards) of foreign language.

The students have the opportunity to choose the educational programme by themselves. Enrollment on the granted programme is based on the competition.

The enrollment procedure of that programme is set by the “Typical rules of the enrollment to the educational organizations of the post-secondary and post-graduate programmes”

The contingent is formed by the state educational order to the preparation of the future academic and teaching professionals. Also, the programme involves the consideration of students, who are able to pay for their education by themselves or using other sources, organizations.

The citizens of the Republic of Kazakhstan have rights to get the state grant through the participation in the competition.

3. Requirements for completion of the course and receiving the diploma

The PhD dissertation defense is confirmed in the closing stages of the PhD programme.

The defense of the PhD dissertation is controlled by the by the Dissertation Council at the university or, by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan.

Those, who has completed the whole curriculum programme will receive the PhD degree.

PhD persons should perform the post-doctoral program or conduct the scientific research under the guidance of a leading scientist for deeper learning of scientific and applied problems.

3.1 Requirements to the key competencies of the graduates:

have an idea about:
- the key milestones of development and paradigm change of the science evolution;
- the knowledge domain, worldview and methodological specifics of natural (socio-humanitarian and economic) sciences;
- scholarly traditions of the suitable area, and their theoretical and practical studies;
- scientific outlooks of the world and Kazakhstan science in terms of the suitable area;
- adaptation of scientific studies into the practical activity;
- standards and rules of cooperation in the scientific commonwealth;
- pedagogical and science-based ethics;

know and understand:
- contemporary trends, directions and common factors of national science in terms of globalization and internalization;
- achievements of the world and Kazakhstan science in terms of the suitable area;
- the social amenability to the science and education;
- the foreign language to the communications with the scientific commonwealth;

be able to:
- organize, plan and implement the research process;
- analyze, evaluate and compare various theoretical concepts in the field of research and make decisions;
- analyze and process information from various sources;
- conduct an independent scientific study, characterized by academic integrity, based on modern theories and methods of analysis;
- generate own new scientific ideas
- share the knowledge and ideas to the scientific community, expanding the boundaries of scientific knowledge;
- choose and effectively use modern research methodology;
- plan and predict the further professional development;
-

have skills of:
- critical analysis, evaluation and comparison of various scientific theories and ideas;
- analytical and experimental research activities;

– planning and forecasting research results;
– public speaking at international scientific forums, conferences and seminars;
– scientific writing and scientific communication;
– planning, coordinating and implementing research processes;
– systematic understanding of the field of study and demonstration of the quality and effectiveness of selected scientific methods;
– participation in scientific events, fundamental scientific domestic and international projects;
– leadership and team management;
– responsible and creative attitude to scientific and scientifically pedagogical activity;
– conducting of the patent search and experience of the transferring scientific information using modern information and innovative technologies;
– protection of the intellectual property rights for scientific discoveries and studies;
– the free communication by the foreign language;

be competent:
– in the field of scientific and educational activities in case of rapid updating and growth of information flows;
– in carrying out of the theoretical and experimental research;
– in the formulation and solution of theoretical and applied problems in scientific research;
– in the realization of the professional and comprehensive analysis of problems in the relevant field;
– in matters of interpersonal communication and human resource management;
– in matters of the university's training of the specialists;
– in the examination of scientific projects and research;
– into ensuring of the permanently professional growth.

3.2 Requirements to the internship realization:

The internship is performed in order to develop the practical skills of the scientific work and professional activity.

The educational program involves:
1) academic internship;
2) work experience internship.

The first one is realized with the purpose of studying of the modern theoretical, methodological and technological achievements of domestic and foreign science.

The work experience internship is performed to transfer theoretical knowledge into practice for improvement the professional level of the students.

4. Educational plan

Academic degree: Doctor of Philosophy (PhD) Period: 3 years

Year	Code	Name of discipline	Component	Credits		Lec/lab/tutorials	Pre-requisites	Code	Name of discipline	Component	Credits		Lec/lab/tutorials	Pre-requisites
				ECTS	RK						ECTS	RK		
1	1 semester							2 semester						
		Mathematical modeling of physical processes	BD	5	3				Pedagogical Internship	BD	11	11		
		Elective discipline	BD	5	3				Scientifically Research work, including internship and dissertation	SRW	19	5		
		Elective discipline 1	PD	5	3									
		Elective discipline 2	PD	5	3									
		Elective discipline 3	PD	5	3									
		Elective discipline 4	PD	5	3									
		Total:		30	18				Total:		30	16		

2	3 semester							4 semester						
		Scientifically Research work, including internship and dissertation	SRW	18	4				Scientifically Research work, including internship and dissertation	SRW	30	7		

2		Research internship	PD	12	3								
		Total:		30	7				Total:		30	7	
3	5 semester							6 semester					
		Scientifically Research work, including internship and dissertation	SRW	30	7				Scientifically Research work, including internship and dissertation	SRW	18	4	
									Writing and defense of doctoral dissertation	FE	12	4	
		Total:		30	7				Total:		30	8	
									Total:		180	63	

CATALOGUE OF ELECTIVE DISCIPLINES

Academic degree: Doctor of Philosophy (PhD)

Code	Name of discipline	Credits	Lec/lab/tutorial
	Basic elective disciplines		
	English language (academic)	3	(0/0/3)
	Profile disciplines		
	Parallel programming	3	(2/0/1)
	Multiprocessor and high-performance computing	3	(2/0/1)
	Modeling in porous systems	3	(2/0/1)
	Contemporary issues of the theory of partial differential equations	3	(2/0/1)
	Elliptic equations on stratified sets	3	(2/0/1)
	Advanced Machine learning	3	(1/0/2)
	Blockchain	3	(2/0/1)
	Advanced Neural networks and applications	3	(1/0/2)
	Applied nonlinear dynamics	3	(2/0/1)
	Advanced theory of information	3	(2/0/1)
	Additional issues in the theory of the equations of mathematical physics	3	(2/0/1)
	Advanced parallel computing	3	(2/0/1)
	Quantum machine and deep learning	3	(2/0/1)

5. Descriptors of the level and content knowledge, skills and competences

The descriptors of the Comprehensive qualification system of the European higher education area represent the results of the learning process, characterized the student's abilities:

1) to be preparing to the chosen specialty;
2) to have the fundamental knowledge of socio-humanitarian disciplines for the creation of the student's own mindset;
3) to know the rights and ethical standards, regulating the relationships among society and, also, representing the formal ethics of the specialist;
4) to be able to obtain and renew knowledge, using the modern educational technologies;
5) to know how to use the modern computer technologies for the data collection, data processing, data analysis and data storage;
6) to be able to continue the other postgraduate programmes;
7) to know the Kazakh, Russian and one foreign language.

6. Diploma Supplement ECTS

The diploma supplement was developed according to the standards of the European Commission, Council of Europe and UNESCO / CEPES. The document is held to imply for academic recognition only. The supplement is not valid without the diploma. The supplement consists of the information about diploma holder, his or her qualification, the content of the program and other relevant information. The model of supplement is based on the European system of transfer or credit transfer (ECTS).

This supplement allows to the graduate to continue the educational process at the foreign universities and to the recognition by the international companies. The European Diploma Supplement is completed in English per individual enquiry and for free charge.

7. Description of the courses

Mathematical models of physical processes

CODE -
CREDIT - 3 (2/0/1)
PREREQUISITE- General Physics, Continuous Mechanics, Mathematical Analysis, Linear Algebra, Ordinary and partial differential equations

Course Description:
The course contains the following chapters:
• Basic laws of Nature (hydromechanics, elasticity, electrodynamics);
• Derivation of mathematical models based on fundamental laws using variational principles;
• Laws of conservation (mass, momentum, energy, etc.);
• A combination of various fundamental laws (for example, a viscous gas flow);
• Analysis of mathematical models;
• Method of similarity and dimension analysis;
• Self-similarity;
• Homogenization of random physical environments and processes.

Course results
The specialist should know the fundamental training of the theoretical foundations and the basic principles of developing models for the numerical simulation of natural physical properties at the end of the course.

Knowledge:
basic concepts of physics;
basic concepts of mathematical analysis;
basic concepts of partial differential equations;
basic concepts of theory of probability and mathematical statistics.

Skills:
continuous mechanics, electrodynamics, equations of mathematical physics, deterministic and stochastic physical processes, boundary value problems for ordinary and partial differential equations.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE COURSE:
Knowledge and skills acquired during the study of the course will form the basis for the further research in the field of mathematical and computer modeling of natural physical processes.

English (academic)

CODE -
CREDIT - 3 (0/0/3)
PREREQUISITE - LNG123

PURPOSE AND TASKS OF THE COURSE
Prepare students for effective study at the PhD program in English at academic level.

BRIEF DESCRIPTION OF THE COURSE
The course combines four basic skills and academic language. Students are encouraged to independently learn and acquire knowledge of the course content.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE
The student will have the listening assignments, take notes while listening, extract key information from the text, predict the content of the text, determine the topic, purpose and basic idea of the paragraph, analyze the paragraph structure, systematize the information logically, plan and write essays, develop skills of critical thinking and comment, participate in the discussion.

Parallel programming

CODE -
CREDIT - 3 (2/0/1)

Course Description:
The course consists the basic of the parallel programming technologies for high-performance computing systems. It covers the basics of parallel computing, modern architectures of high-performance computing systems, parallel programming technologies MPI, OpenMP, MPI + OpenMP, and features of their implementation and usage. Special attention of the course is paid to the methods of building efficient parallel software. The course material includes examples of solving typical problems of mathematical physics. It is assumed that after listening of this course, students will be able to write parallel programs and independently run them on a super computer.

Multiprocessor and high performance computing

CODE -
CREDIT - 3 (2/0/1)

Course Description:
The course is intended for students, who plan to use parallel computer technologies to solve practical and computationally intensive tasks. High-performance computing using parallel computing systems, modern trends of computers and high-performance programs. So that, the course involves the principles of building parallel computing systems, mathematical models of parallel algorithms and programs for analyzing the effectiveness of parallel computing.

Students will learn:
- how to analyze the performance of an MPI program
- how to determine its weak and strong scalability
- how to apply acceleration options for parallel applications.

The consolidation of the received material is planned to be carried out on a super computer.

Porous Modeling

CODE -
CREDIT - 3 (2/0/1)

PURPOSE AND TASKS OF THE COURSE
The purpose and objectives of the discipline are based on the modeling processes in porous systems.

BRIEF DESCRIPTION OF THE COURSE
The course includes the fundamentals of continuum mechanics, such as the description of continuum motion, the fundamental laws of dynamics, familiarity with stress tensors, introductions to hydrodynamics, classical laws of continuum mechanics, thermodynamics, and an introduction to the theory of elasticity.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE COURSE
PhD student should know:
- the fundamental laws of continuum mechanics;
- the main characteristics of the continuum;
- various models of continuous media;
- the main tensors of the theory of elasticity and hydrodynamics.
- how to describe the various processes of the theory of elasticity, hydrodynamics and porous media;
- how to determine the main characteristics of the continuum;
- how to independently expand the knowledge gained to describe more complex systems of the theory of composite materials and underground porous media.

Current issues in the theory of partial differential equations

CODE -
CREDIT - 3 (2/0/1)

PURPOSE AND TASKS OF THE COURSE

The purpose of the discipline is the ability to independently solve partial derivatives, related to differential equations.

Objectives of the discipline: current issues and methods for solving partial differential problems, in particular spectral methods.

BRIEF DESCRIPTION OF THE COURSE
- finite-dimensional theory of operators and applications for solving differential equations,
- infinite-dimensional theory of operators and applications for solving differential equations
- compact theory
- restricted operators
- unlimited operators
- non-compact operator theory

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE
PhD student should know:
- basics of the spectral theory of operators for solving diff. partial differential equations;
- how to solve the basic equations of mathematical physics by spectral methods.

Elliptic equations on stratified sets

CODE -
CREDIT - 3 (2/0/1)

AIM AND TASKS OF THE COURSE
The purpose and task of the discipline are based on the mathematical analysis on stratified sets and its application to some processes in highly heterogeneous media, leading to elliptic equations.

BRIEF DESCRIPTION OF THE COURSE

The course involves the definition of a stratified set and a stratified measure. In terms of this measure, analogues of the classical operations are defined as: gradient, divergence, Laplacian, as well as more general second-order elliptic operators. Also, the analogues of classical integral identities are proved for the introduced operations. Further, we will discuss about the question of the solvability of an analogue of the Dirichlet problem and some qualitative properties of solutions grouped around the strong maximum principle.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE

PhD student should know:
- the concept of a stratified set, measure and integral on it;
- analogues of classical differential operations on
stratified sets;
- some models of processes in highly inhomogeneous environments;
- Basic concepts related to the solvability of the Dirichlet problem.

PhD student should be able to:
- integrate scalar functions by stratified measures;
- apply analogs of integral identities;
- simulate small movements under the action of external loads in systems composed of strings, membranes and elastic bodies;
- prove the theorem on the weak solvability of the Dirichlet problem;
- prove theorems on the qualitative behavior of solutions of elliptic equations on stratified sets.

Advanced machine learning

CODE -
CREDIT - 3 (1/0/2)

AIM AND TASKS OF THE COURSE

The aim of the discipline is the preparation specialists, who knows basic machine learning skills such as Supervised, Unsupervised, Reinforcement Learning

Course objectives
- mastering of the main Python libraries
- data manipulation
- models optimization

BRIEF DESCRIPTION OF THE COURSE

1. Pandas, Numpy, Scipy, MySql, SQLite, SQLAlchemy, Seaborn, Matplotlib, Bokeh, Scrapy.
2. Processing CSV, XLS, JSON files.
3. Supervised, Unsupervised, Reinforcement Learning
4. Case studies.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE COURSE

PhD student should know:
- Pandas, Numpy, Scipy, MySql, SQLite, SQLAlchemy, Seaborn, Matplotlib;
- how to work on Anaconda, Spyder, Jupyter notebook
- how to solve problems of classification, regression, clustering, etc .;
- how to process the large data;
- Scraping, Wrangling, Crawling data.

Blockchain

CODE -
CREDIT - 3 (2/0/1)
PREREQUISITE - cryptography

AIM AND TASKS OF THE COURSE

The purpose of the discipline is the development of decentralized applications for Solidity and Java Script.

Objectives of the discipline
- mastering the language Solidity
- mastering the Java Script language and developing the blockchain
- development of decentralized applications

BRIEF DESCRIPTION OF THE COURSE

- blockchain cryptographic fundamentals, RSA, ECC protocols
- Solidity
- java script
- decentralized applications

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE
As a result of studying the discipline should know:
- blockchain cryptographic fundamentals, RSA, ECC protocols;
- Solidity language;
- how to build decentralized applications for Solidity

Advanced Neural Networks and Applications
CODE -
CREDIT - 3 (1/0/2)
PREREQUISITE - Machine learning, neural networks, main Python libraries, mathematical analysis, statistics, optimization, graph theory.

AIM AND TASKS OF THE COURSE
The purpose and objectives the discipline are the development of modern neural network architectures, as well as their applications in NLP, pattern recognition.

BRIEF DESCRIPTION OF THE COURSE
1. Feedforward, Backpropagation, Gradient Descent, Stochastic Gradient Descent
2. CNN, RNN, LSTM on PyTorch for solving classification and regression problems
3. Pipelining at Keras
4. SQLAlchemy, SQLite
5. Bokeh
6. Seaborn

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE
PhD student should know:
- the mathematical basis of modern deep neural networks
- how to build deep neural networks
- how to optimize deep neural networks

Applied nonlinear dynamics

CODE -
CREDIT - 3 (2/0/1)
PREREQUISITE –MAT205

AIM AND TASKS OF THE COURSE

- show students how to recognize basic oscillatory phenomena in complex, at first glance, oscillatory processes of a particular nature and reduce the initial problem to the analysis of these models;

- achieve the understanding of the main nonlinear phenomena on simple models and systems (resonance, stability, parametric amplification and generation, preservation of invariants, generation of harmonics and frequency multiplication, self-modulation, chaos production, etc.);

- acquaint and teach them to use the basic methods of nonlinear dynamics (phase plane and phase space, point mappings, averaging, discontinuous oscillations, many scales);

- to instill the basic skills of an interdisciplinary approach to real non-linear phenomena

BRIEF DESCRIPTION OF THE COURSE

Nonlinear dynamics is a section of modern applied mathematics including nonlinear dynamic systems of the most diverse nature (physical, chemical, biological, economic, social, etc.). A dynamic system is a system whose state changes (discretely or continuously) in time. Nonlinear dynamics use nonlinear models in the study of systems — most often differential equations and discrete mappings. Nonlinear oscillatory processes obey the general laws and are described by uniform mathematical models. This unity allows a much deeper understanding of the essence of the phenomena in each specific situation and, in addition, to take advantage of the experience gained in studying some systems for analyzing processes in others.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE

The PhD student should know at the end of the course:

- the basic terms, concepts, methods and approaches of nonlinear dynamics and the theory of bifurcations used to analyze the behavior of nonlinear systems, the technology of computer simulation of nonlinear dynamics processes, based on qualitatively numerical methods of analysis;
- problem statements and the basic laws of the dynamic behavior of mathematical models;

Be able to:

- obtain mathematical models of nonlinear dynamic systems;
- formulate the problem of studying these models and choose adequate theoretical and numerical methods for their solution;
- find the stationary modes of the systems and the areas of their existence in the parameter space;
- investigate their bifurcations on the basis of applying the methods and techniques of qualitatively-numerical research of nonlinear dynamic systems;
- plan a computational experiment on a computer.

Information Theory - Advanced

CODE -
CREDIT - 3 (2/0/1)

AIM AND TASKS OF THE COURSE

- the concept and types of information systems;
- the concept of management as a science;
- the concept of entropy, information and methods for their evaluation;
- methods of quantitative evaluation of information;
- theoretical and practical aspects of optimal (efficient) coding;
- theoretical and practical aspects of robust coding;
- models of signals, data transmission systems, modulation and demodulation, sampling signals;
- application of the theory of noise-resistant coding in data processing systems.

BRIEF DESCRIPTION OF THE COURSE

This course consists the information theory, as the theoretical basis of information and communication technologies. Information theory explains many key aspects of communication and data processing. The theory considers the concepts of entropy, information, optimal coding methods, noise immunity coding methods, and signal models. Recently, information theory has been successfully applied in problems of machine learning and artificial intelligence.

The purpose of this course is the explanation of the fundamental concepts of the information theory and illustration of their applications. The course provides some methods for software prototyping based on linear algebra and information theory. During the course, students gain theoretical knowledge and practical skills in developing software of this type.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE:

- understand what entropy and information are,
- understand effective coding techniques,
- understand noise immunity coding methods
- understand mathematical models of signals
- determine when and why certain signal and data processing techniques should be used.
- data processing software based on information theory
- information theory methods for solving practical problems (coding, cryptography, data processing)

Additional questions in the theory of equations of mathematical physics

CODE -
CREDIT - 3 (2/0/1)
PREREQUISITE –MAT101

AIM AND TASKS OF THE COURSE

The purpose of the discipline is the presentation of the classical as well as modern methods for solving problems of MFIs in particular in the theory of parabolic equations.

BRIEF DESCRIPTION OF THE COURSE

The course involves the development of methods for solving problems of Stefan, Verigin, and the generalized heat equation. Also, course involves methods for solving inverse problems and applications of modern methods in the simulation of electro contact processes.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE COURSE
The PhD student should know about the construction of mathematical models and have knowledge to solve direct and inverse problems of the Stefan type.

Parallel computing - advanced level

CODE -
CREDIT - 3 (2/0/1)
PREREQUISITE –MAT101, MAT 102, MAT 103

OBJECTIVES AND TASKS OF THE COURSE

- to familiarize the basic principles, techniques, concepts and paradigms of parallel computing, and the development of parallel programs. Moreover, to teach how to develop and implement parallel algorithms based on MPI, OpenMP, OpenACC technologies using cluster and supercomputer systems.

BRIEF DESCRIPTION OF THE COURSE
The course considers the basic concepts of parallel computing and parallel programming.
The course contains the following sections: review of the parallel computing systems and their classification, characteristics of multiprocessor and multi-core systems, evaluation of the

effectiveness of parallel computing, analysis of the complexity of calculations and evaluation of the possibility of parallelization. Also, it includes a general scheme for developing parallel methods, programming for systems with shared and distributed memory. During the course PhD students acquire skills of development of the parallel programs in the C ++ programming language using MPI, OpenMP, OpenACC technologies.

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE
The PhD student should have knowledge and notion of the parallel computing principles and methods, about identification of the parallel systems and development of the parallel programs for MPI-based distributed systems, usage OpenMP technology, and create heterogeneous programs using the OpenACC standard.

Quantum machine and deep learning

CODE -
CREDIT - 3 (2/0/1)
PREREQUISITE - Quantum mechanics, machine and deep learning, functional analysis, information theory

AIM AND TASKS OF THE COURSE
Mastering of the basic theoretical positions with CC, CQ, QC, QQ directions

BRIEF DESCRIPTION OF THE COURSE
- Machine learning on quantum computers
- Applications of classical learning for quantum problems
- The theory of quantum learning
- Applications

KNOWLEDGE, SKILLS, SKILLS TO COMPLETE THE COURSE
To have necessary knowledge of the quantum machine learning algorithms based on the Grover Search, the HHL algorithm, quantum neural networks, quantum Markov models, noise and noise-free data, variation circuits.

The educational program of scientifically pedagogical doctoral studies includes pedagogical and research internship.
Pedagogical practice can be conducted during the period of theoretical course with the aim to form practice skills and methods of teaching.
The research internship focuses on familiarization with the latest theoretical, methodological and technological achievements of domestic and foreign science. Moreover, it includes the notion of modern methods of scientific research, processing and interpretation of experimental data.

Research work of scientifically pedagogical PhD program should:
– comply with the main issues of the specialty related with the doctoral dissertation;
– be relevant, contain scientific novelty and practical significance;
– be based on the modern theoretical, methodical and technological achievements of science and practice;
– be carried out with modern research methods;
– contain research (methodical, practical) sections of the main defended positions;

– based on the best international experience of the relevant field of knowledge;
– be implement with advanced information technologies;
– contain experimental research (methodical, practical) sections of the main defended positions

Defense of the doctoral dissertation

CODE -
CREDIT - 12

The purpose of the doctoral dissertation is assessment of the scientific-theoretical and research-analytical level of the PhD candidate. Thus, the dissertation involves the professional and managerial competencies, readiness for independent performance of professional tasks and compliance to the requirements of the professional standard and PhD program.

SHORT DESCRIPTION
Defense of the doctoral dissertation focuses on the evaluation of scientific work done by PhD student. This work considers the independent research based on the theoretical concepts, the totality of which can be qualified as a new scientific achievement. Also, the scientific work can be represented in the form of solution of the scientific problem, or as scientifically grounded technical, economic or technological solutions, which could influence on the development of country's economy.

Therefore, defense of the doctoral thesis is the final stage of PhD program, which has the next requirements:
The topic of the thesis should be related to the priority directions of the development of science and / or state programs or programs of fundamental or applied research.
The content, goals and objectives of the dissertation, and the scientific results should be strictly corresponding to the topic of the thesis.
The doctoral thesis needs to be compliant with the principles of independence, internal unity, scientific novelty, authenticity and practical value.

Content