Federal State Autonomous Educational Institution of Higher Education
"Peoples' Friendship University of Russia"

Academy of Engineering
(Name of the main educational unit (MEU)- of the developer of the EP of HE)

THE WORKING PROGRAM OF THE DISCIPLINE

Artificial Neural Networks (Reinforcement Learning)
(Name of the discipline/module)

Recommended by Methodological Council for the Education Field for the direction of training/specialization

01.04.02 Applied mathematics and computer science
(code and name of the direction of training / specialization)

The development of the discipline is carried out within the framework of the implementation of the main professional educational program of higher education (EP HE):

Ballistic Design of Space Complexes and Systems
(name (profile/specialization) EP HE)

2022 г.

1. GOAL OF MASTERING THE DISCIPLINE

Goal of mastering the discipline «Artificial Neural Networks (Reinforcement Learning)» is to study the method of constructing automatic control systems based on artificial neural networks, mastering methods for solving basic control problems using neural networks.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline " Artificial Neural Networks (Reinforcement Learning)" is aimed at developing the following competencies:

Table 2.1. The list of competencies formed by students in the course of mastering the discipline (the results of mastering the discipline)

Code	Competence	Competence achievement indicators (within this discipline)
UC-1	Able to search, critical analysis of problem situations based on a systematic approach, develop an action strategy	UC-1.1 - Analyzes the task, highlighting its basic components; UC-1.2 - Determines and ranks the information required to solve the problem; UC-1.3 - Searches for information to solve the task for various types of requests; UC-1.4 - Offers options for solving the problem, analyzes the possible consequences of their use
UC-7	Able to: search for the necessary sources of information and data, perceive, analyze, memorize and transmit information using digital means, as well as using algorithms when working with data received from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data	UK-7.1 - Searches for the necessary sources of information and data, perceives, analyzes, remembers and transmits information using digital means, as well as using algorithms when working with data received from various sources of data in order to effectively use the information received to solve problems; UK-7.2 - Evaluates information, its reliability, builds logical conclusions based on incoming information and data.
PC-1	Able to formulate goals, objectives of scientific research in the field of applied mathematics and informatics, computer technology and modern programming technologies, choose methods and means of solving problems	PC-1.1 - Possesses fundamental knowledge obtained in the field of mathematical and (or) natural sciences, programming and information technology PC-1.2 - Able to find, formulate and solve standard problems in their own research activities in the field of applied mathematics and informatics, computer technology and modern programming technologies PC-1.3 - Has practical experience in research activities in the field of applied mathematics and informatics, computer technology and modern programming technologies

Code	Competence	Competence achievement indicators (within this discipline)
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of the objects and processes under study related to professional activities in the field of training and participate in their implementation in the form of software products	PC-2.1 - Knows modern theoretical and experimental methods for developing mathematical models, innovative design tools and elements of architectural solutions for information systems PC-2.2 - Able to develop and implement algorithms for mathematical models based on languages and packages of applied modeling programs PC-2.3 - Has practical experience in developing options for implementing information systems using innovative tools

3. THE PLACE OF DISCIPLINE IN THE STRUCTURE OF EP HE

Discipline "Artificial Neural Networks (Reinforcement Learning)" belongs to obligatory part / part formed by participants in educational relations of block Б1 О.02.07 НЕ.

Table 3.1. The list of components of the EP HE that contribute to the achievement of the planned results of the development of the discipline

Code	Competence	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
UC-1	Able to search, critical analysis of problem situations based on a systematic approach, develop an action strategy	Artificial Neural Networks (Deep Learning)	Research work
UC-7	Able to: search for the necessary sources of information and data, perceive, analyze, memorize and transmit information using digital means, as well as using algorithms when working with data received from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data	Artificial Neural Networks (Deep Learning)	Research work
PC-1	Able to formulate goals, objectives of scientific research in the field of applied mathematics	Artificial Neural Networks (Deep Learning)	Research work

Code	Competence	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
	and informatics, computer technology and modern programming technologies, choose methods and means of solving problems		
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of the objects and processes under study related to professional activities in the field of training and participate in their implementation in the form of software products	Artificial Neural Networks (Deep Learning)	Research work

4. SCOPE OF THE DISCIPLINE AND TYPES OF LEARNING ACTIVITIES

The total labor intensity of the discipline " Artificial Neural Networks (Reinforcement Learning)" is 5 credit units.

Table 4.1. Types of educational work for full-time education

Вид учебной работы		ВСЕГО, ак.ч.	Семестр(-ы)			
			1	2	3	4
Classroom lessons (total)		68			68	
Including:						
Lectures (L)		34			34	
Practical lessons (PL)		17			17	
Seminars (S)		17			17	
Laboratory work (LW)		*81*			*76*	
Control (exam/test with assessment), total		*27*			*36*	
Total labor intensity	hour	**180**			**180**	
	CU	**5**			**5**	

4. CONTENT OF THE DISCIPLINE

Table 5.1. Content of the discipline (module) by types of educational work

Name of discipline section	Content of the section (topics)	Types of educational work *
Section 1 The Reinforcement Learning Problem	Topic 1.1. The model of interaction of agent with environment, Link with optimal control, Markov chain.	L
	Topic 1.2. Markov decision process (MDP).	L, S
	Topic 1.3. Reinforcement learning algorithms, Conditions of Reinforcement learning problem,	L, S

Name of discipline section	Content of the section (topics)	Types of educational work *
	Comparison with supervised learning, Conception of model-free algorithms.	
	Topic 1.4. Classification of RL algorithms, Evaluation criterion of RL algorithms, Design of reward function	L, S
Section 2 Meta-heuristics	Topic 2.1. Random Search, Hill Climbing, Annealing algorithm.	L, S
	Topic 2.2. Evolutionary algorithms, Genetic algorithms	L, LW
	Topic 2.3. Evolutionary strategy	L, LW
Section 3. Classical theory	Topic 3.1. Bellman equation, Optimal strategy, Bellman's optimality principle, Bellman optimality equation, Bellman optimality criterion, Dynamical programming, Exponential smoothing,	L, S
	Topic 3.2. Table algorithms, Monte-Carlo algorithm, Stochastic approximation, Temporal Difference, Q-learning. SARSA	L, S
Section 4. Value-based approach	Topic 4.1. Deep Q-learning, Q-grid, parametric Q-function, modification of DQN, Double DQN, Dueling DQN, Noisy Nets, Prioritized DQN), Multi-step DQN, Retrace, Z-function.	L, S
Section 5. Policy gradient approach	Topic 5.1. Policy gradient approach, Surrogate function, Disengagement of external and internal stochastics.	L, S
Section 6. Imitation learning	Topic 6.1. Behavior cloning, Guided Cost Learning, Generative Adversarial Imitation Learning, Internal motivation, Combination of motivation	L, S
	Topic 6.2. Random net distillation, Invers dynamic model, Hierarchic reinforcement learning, Partially observable environment.	

6. TECHNICAL EQUIPMENT FOR THE DIDISCIPLINE

Table 6.1. Technical equipment for the discipline

Audience type	Audience equipment	Specialized educational / laboratory equipment, software and materials for mastering the discipline (if needed)
Lection	An auditorium for lecture-type classes, equipped with a set of specialized furniture; board (screen) and technical means of multimedia presentations.	Computer classroom equipped with 25 workstations with a personal computer, specialized software for laboratory work and practical lessons
Labor	An auditorium for laboratory work, individual consultations, current control and intermediate certification, equipped with a set of specialized furniture and equipment.	Classroom equipped with 30 workstations for lectures and group lessons

Seminar	An auditorium for conducting seminar-type classes, group and individual consultations, current control and intermediate certification, equipped with a set of specialized furniture and technical means for multimedia presentations.	Computer classroom equipped with 25 workstations with a personal computer, specialized software for laboratory work and practical lessons
Computer class	Computer class for conducting classes, group and individual consultations, current control and intermediate certification, equipped with personal computers (in the amount of ____ pcs.), Board (screen) and multimedia equipment презентаций.	
Individual work	An auditorium for independent work of students (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the EIES.	

7.INFORMATION SUPPORT OF THE DISCIPLINE

Main literature:

1. R.S. Sutton and A.G. Barto Reinforcement Learning: An Introduction. The MIT Press Cambridge, Massachusetts London, England, 2018. – 552 pp.
2. С. Николенко, А. Кадурин, Е. Архангельская. Глубокое обучение. Погружение в мир нейронных сетей. СПб.: Питер, 2018. - 480 с.: ил. - ISBN 978-5-496-02536-2

Additional literature:

1. A. Zai B. Brown. Deep Reinforcement Learning in Action. Manning Publications Co. Shelter Island, NY 11964, 2020. – 360 pp. ISBN: 9781617295430
2. ……

1. ELS of RUDN University and third-party ELS, to which university students have access on the basis of concluded agreements:
RUDN Electronic Library System - RUDN EBS http://lib.rudn.ru/MegaPro/Web
- ELS "University Library Online" http://www.biblioclub.ru
- EBS Yurayt http://www.biblio-online.ru
- ELS "Student Consultant" www.studentlibrary.ru
- EBS "Lan" http://e.lanbook.com/
- EBS "Trinity Bridge"

2. Databases and search engines:
- electronic fund of legal and normative-technical documentation http://docs.cntd.ru/
- Yandex search engine https://www.yandex.ru/
- Google search engine https://www.google.ru/
- abstract database SCOPUS http://www.elsevierscience.ru/products/scopus/

Educational and methodological materials for independent work of students in the course of mastering the discipline/module*:

1. Course of lectures
2. Laboratory workshop

8. EVALUATION MATERIALS AND SCORE-RATING SYSTEM FOR ASSESSING THE LEVEL OF FORMATION OF COMPETENCES IN THE DISCIPLINE

In accordance with the requirements of the OS VO RUDN University, for attestation of students for compliance of their personal achievements with the planned discipline learning outcomes, assessment tools funds have been created (VF is presented in Annex 1).

The teacher has the right to change the number and content of assignments given to students (student), based on the contingent (their level of preparedness).

Developer:

Prof. _____ Diveev A.I.

Head of Programm

Prof. _____ Razoumny Yu.N.

Head of Department

Prof. _____ Razoumny Yu.N.