Ministry of Education and Science of Ukraine
State Higher Educational Institution
National Mining University

System Analysis and Control Department

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WORKING PROGRAM OF EDUCATIONAL DISCIPLINE
VK9 "Mathematical Modeling and Analysis of Dynamic Systems"
For masters of specialty 124 "System Analysis"

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NMU
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INTRODUCTION

The programmed results of the master's degree in system analysis are defined in the standard of higher education by specialty 124 System Analysis.

In the educational-professional program of the State Higher Educational Institution "NMU" [2.1] the distribution of programmatic learning outcomes was carried out according to the organizational forms of the educational process. The discipline "Mathematical modeling and analysis of dynamic systems" includes the following competencies and learning outcomes:

FK1 - Ability to develop and analyze mathematical models of natural, technological, economic and social facilities and processes;

FK2 - Ability to plan and conduct system studies, perform mathematical and information modeling of dynamic processes;

FK8 - Ability to develop a forecasting tool dynamics of processes of different nature in deterministic and stochastic environment and assess the quality of forecasts;

PRN3 Know the methods of forecasting the dynamics of processes of different nature, be able to develop prediction functions;

PR96 Know and be able to apply the methods of evolutionary modeling and genetic optimization methods, inductive modeling methods and mathematical apparatus of fuzzy logic, neural networks, game theory and distributed artificial intelligence, etc .;

RNS1 Know and be able to identify (estimate) the parameters of mathematical models of objects of management in real time with changes in its dynamics and the effects of random disturbances, using the measured signals of the input and output coordinates of the object;

RNS4 To analyze the stability of dynamic systems, to apply stochastic regression models and models in the state of space to describe the dynamics of processes of different nature.

In addition to the professional learning outcomes while studying the discipline, the bachelor must master the following general learning outcomes:

ZRN2 Be able to search information in specialized literature in the field of system analysis using a variety of resources: journals, databases, on-line resources.

ZRN3 Be able to process, analyze, systematize scientific and technical information, generalize advanced national and foreign experience in system analysis.

ZRN4 To develop and apply in the professional activity their creative abilities, to organize a workplace, to plan working hours

ZRN5 Exercise curiosity, risk aversion, thinking skills, inspire new ideas, incarnate them, ignite them, combine and experiment

The purpose of the discipline "Mathematical modeling and analysis of dynamic systems" is the formation of future specialists in theoretical knowledge and practical skills of mathematical formalization of the behavior of systems of various nature, the ability to apply the theory of control, optimization in the analysis of dynamic systems.

Realization of the goal requires the transformation of the program results of training in discipline, and the selection of the content of the discipline according to this criterion.

Requirements for the structure of the work program of disciplines are given in [2.5].

1 FIELD OF USE

The work program is designed for

- implementation of a competent approach in shaping the structure and content of discipline;
- internal and external quality control of training specialists;
- accreditation of the educational program in the specialty.

The work program sets:

- scope and terms of teaching discipline;
- designation of physical quantities;
- disciplinary learning outcomes and their level of difficulty;
- thematic plan and the distribution of the volume of organizational forms of the educational process;
- requirements to the structure and content of an individual task;
- task for the independent work of the applicant;
- generalized diagnostic tools, criteria and procedures for assessing the achievements of applicants;
- the composition of the complex of teaching and methodological provision of discipline.

2 NORMATIVE REFERENCES

The work program of the discipline is developed on the basis of the following normative documents:

2.1 Educational program of preparation of bachelor's degree in specialty 124 "System analysis" / Ministry of Education and Science of Ukraine, National Mining University - D.: NMU, 2017. - 23 p.

2.2 Resolution of the Cabinet of Ministers of Ukraine dated December 30, 2015, No. 1187 Licensing conditions for the educational activities of educational institutions (Decree of the Cabinet of Ministers of Ukraine of December 30, 2015, No. 1187 "Licensing conditions for the educational activities of educational institutions".

2.3 Draft Standard of Higher Education Bachelor Degree Specialty 124 System Analysis.

2.4 Law of Ukraine "On Higher Education".

2.5 Standard of Higher Education of the State Higher Educational Institution "NMU" Design of the educational process. Dnipropetrovsk: NMU, 2016. - 74 p.

3 THE SCOPE AND TERMS OF TEACHING DISCIPLINE

Total amount - 3 credits ECTS (90 academic hours).

It is taught at the 5th year, in the 1st semester, in the 1 st (7 th week) and the 2 nd quarter (6 th weeks).

4 DESIGNATION OF PHYSICAL QUANTITIES

x (t) is a vector that describes the state of the system;
u (t) is the velocity vector;
H (t) - Hamiltonian.

5 EXPECTED DISCIPLINARY LEARNING OUTCOMES

The code and the content of educational outcomes for an educational-professional program	Code and content of disciplinary learning outcomes (DLO)
1	2
PRN3 Know the methods of forecasting the dynamics of processes of different nature, be able to develop prediction functions;	DRN3-1 Analyze the domain and give a formal description of real systems.
	DRN3-2 To develop mathematical models of objects and processes, using procedures of the formal representation of the system and the results of research of real natural or socio-economic systems.
	DRN3-3 To apply methods of statistical modeling and forecasting, to perform evaluation of model output data
	DRN3-4 To develop mathematical models in the form of systems of differential equations, to use methods of solving differential equations
PRN6 Know and be able to apply the methods of genetic evolution modeling and optimization methods, inductive methods and mathematical modeling of fuzzy logic, neural networks, game theory and distributed artificial intelligence, etc.	DRN6-1 On the basis of methods of system analysis, to be able to understand deeply the features of natural, socio-economic and environmental processes that are subject to research and automation.
	DRN6-2 Analytically investigate mathematical models of objects and processes on the subject of existence and unity of its solution.
	DRN6-3 Ability to apply methods of regularizing a mathematical model in case of its incorrectness
RNS1 Know and be able to identify (estimate) the parameters of mathematical models of objects of control in real time in conditions of changing its dynamics and the effects of random perturbations using the measured signals of the input and output coordinates of the object	DNS1-1. Choose input and output parameters of the system
	DNS1-2 Identify the parameters of a mathematical model, analyze the suitability of a model for a real object or process.
	DNS1-3 Perform structural decomposition of the system by means of mathematical dependencies, heuristic approach, operational research

	DNS1-4 Identify the parameters of a mathematical model, analyze the adequacy of a model for a real object or process, using analytical and experimental methods for checking the consistency, sensitivity, realism and performance of the model
RNS4 To analyze the stability of dynamic systems, to apply stochastic regressive models and models in the state of space to describe the dynamics of processes of different nature	DNS4-1 Compose mathematical models of control systems, be able to mutually convert them
	DNS4-2 Be able to take into account nonlinear dependencies between system variables
	DNS4-3 Know the methods of analyzing the stability of control systems
	DNS4-4 To analyze the environment of the operation of the research object

6 THEMATIC PLAN AND DISTRIBUTION OF THE VOLUME OF DISCIPLINE BY TYPES OF TRAINING SESSIONS

DLO code	**Kind and subjects of training sessions**	**Amount,** *hours*		
		aud	**CPC**	**all**
1	**2**	**3**	**4**	**5**
	lectures	**26**	**20**	**46**
DRN3-1 DNS1-4 DNS4-1	Elementary mathematical models. Fundamental laws of nature. Variation principles. Hierarchical approach to model construction. Examples of models derived from the fundamental laws of nature	2	1	3
DRN3-1 DNS1-2	Universality of mathematical models. Liquid in U-shaped vessel. Sharp electric circuit. Small oscillations in the interaction of two biological populations. The simplest model for changing wages and employment.	2	1	3
DRN3-2 DNS4-1	Some models of the simplest nonlinear objects	2	1	3
DRN3-3 DNS1-3	General scheme of Hamilton's principle. Dynamic system "ball - spring"	2	1	3
DRN3-1 DNS1-1 DNS1-4	Universality of mathematical models. Dynamics of cluster amoeba. Random Markov process. Examples of analogy between mechanical, thermodynamic and economic objects	2	1	3
DRN3-4 DNS4-1	Organization of advertising campaign. Interdependence of enterprises' debts	2	1	3
DRN3-3 DNS4-1	Dynamic models of socio-economic systems. One-sector dynamic model of industry development in pure competition	2	2	4

DRN3-3 DNS1-1	Two-factor dynamic optimization model for the industry. A dynamic model of cyclical smoothing with the interaction of economies	2	2	4
DRN3-2 DNS4-3	Two-factor dynamic optimization model for the industry. A dynamic model of cyclical smoothing with the interaction of economies	2	2	4
DRN6-1 DNS4-2	Dynamic models of competitive systems with complete and incomplete information	2	2	4
DRN6-2 DNS1-1	Mathematical models of social, political processes and systems	2	2	4
DRN6-3	Dynamical systems management. Criterion of controllability of linear and nonlinear systems.	2	2	4
DRN6-1 DNS4-4	Software management in non-stationary systems. Class of admissible departments. The task of constructing a software control. The task of localization of movement. Pulse control software	2	2	4
	Laboratory work	**14**	**30**	**44**
DRN3-1 DNS4-2	Dynamics model of an industrial enterprise with participation external investment as a form of state support	2	4	6
DRN3-3	Model of dynamics of an industrial enterprise with non-linear production functions	2	4	6
DRN6-3 DNS4-1	The model of the industrial enterprise that uses one-time credit resource provided uniform debt repayment	2	4	6
DRN3-1 DNS4-2	Generalized dynamic model of strategic development analysis of an enterprise with the use of financial tools and combined funding schemes	2	4	6
DRN3-3 DNS1-2 DNS4-1	Advertising effectiveness. Supply and demand. Model of natural growth of output. Increase of release in conditions of competition	2	4	6
DRN6-2 DNS4-3	Market model with forecasted prices. Keynes dynamic model. Neoclassical growth model	2	5	7
DRN3-1 DNS1-4 DNS4-4	Research of stability and controllability of dynamic systems	2	5	7
	Total	**40**	**50**	**90**
	Lectures (classroom - 2 hours per week)	**26**	**20**	**46**
	Laboratory classes (classroom - 1 hour per week)	**14**	**30**	**44**
	Final (semester) control-differentiated credit: II semester, 4 quarter			

7 REQUIREMENTS FOR INDIVIDUAL TASKS

When studying the discipline provides for the implementation of an individual task.

The task is carried out in accordance with the methodological recommendations [15].
Purpose of the task:
1) generalization of competences acquired during the training;
2) development of the ability to apply discipline knowledge to develop mathematical models of specific processes and systems.
3) acquisition of the skills of calculating the parameters of the system or process.

In view of the task to carry out the following operations:
1) analyze a particular object or process, identify its main characteristics, components, properties;
2) compile a mathematical model of an object or process;
3) solve a model example; to prove the adequacy of the constructed mathematical model.

When evaluating the task, account shall be taken of:

- methods used;
- correctness and completeness of solving tasks;
- literacy, conciseness and logical sequence of presentation;
- ability to use computer tools for solving problems;
- correct execution of the explanatory note and its timely submission;
- Independence of performance (is diagnosed during protection).

8 TASKS FOR SELF-LEARNING

The main tasks for independent work include:

- preliminary processing of information support for each topic;
- preparation for current control - solving tasks of self-control for each topic;
- performance of an individual task;
- preparation for the protection of individual tasks;
- preparation for the final (semester) control.

9 FORM OF FINAL CONTROL, DIAGNOSTIC TOOLS, CRITERIA AND EVALUATION PROCEDURES

9.1 Form of final control

The form of final control is a differential score.

Assessment of the level of formation of disciplinary competencies in the form of diff. the score may also be made without the student's participation, based on the results of the current control.

9.2 Forms of current control

Determination of the level of the formation of disciplinary learning outcomes during the current control is carried out for:

- a certain section of the work program of discipline;
- laboratory work (inspection and protection);

9.3 Diagnostic tools

9.3.1 Generalized diagnostic tools

Diagnostic tools are presented in the form of theoretical questions and concretized tasks with numerical input data and are designed to assess the student's ability:

- differentiate, integrate and unify knowledge;
- apply rules, methods, principles, laws in specific situations;
- interpret circuits, graphs, diagrams;
- analyze and evaluate the facts, events and predict the expected results from the decisions made;
- to present material on paper Logically, consistently, with the requirements of the current standards.

9.3.2 Specified diagnostic tools

The precise diagnostic tools that are directly used for control measures during lectures are formed on the basis of generalized numerical or other concretization of generalized means in the form of closed and open type tests.

9.4 Criteria and evaluation procedures

9.4.1 Lecture material

The evaluation of the results of the accomplished tasks is carried out by comparing them with the standards - samples of correct and complete answers by identifying the level of competence generation based on the analysis of the student's response using the coefficient of assimilation as a percentage that adapts the value of the assessment to the ECTS scale:

$$P_i = a / m\ (\%),$$

where – a number of correct answers or performed essential operations of decision standards; m – is the total number of questions or essential operations of the decision benchmark.

The results of the students' achievements (as a percentage) obtained from the described scheme are presented in the estimations of the ECTS and the national scale:

Marks, %	Grade
National Differentiated Scale	
90-100	Excellent
74-89	Good
60–73	Satisfactory
1-59	Fail
ECTS	

90-100	A
82-89	B
74-81	C
64–73	D
60–63	E
35-59	Fx
1-34	F

If the level of student achievement below 60% is fixed or if the student does not appear on a control event, then he is rated "Fx" and "unsatisfactory". In such cases, the student is obliged to further master this topic of classes and undergo a re-evaluation of his learning outcomes.

9.4.2 Laboratory work

Each laboratory work is evaluated by the quality of the report by means of the coefficient of assimilation or by the expert method, when the maximum assessment is made subject to the following conditions:

- compliance with the report on the implementation of laboratory work methodological recommendations;
- correctness of execution;
- possession of theoretical knowledge on which the subject of research is based;
- possession of experimental research methods;
- general and professional literacy, conciseness and logical sequence of presentation of the material;
- compliance of the report with the current standards;
- availability of references to sources of information;
- independence of performance (it turns out during protection).

The level of achievements based on the results of a complex of laboratory work by discipline is defined as the average value of the results of the current control of each.

During the examination the evaluation for laboratory work is determined by the percentage of the correct steps of the algorithm for its implementation.

Integral assessment of achievements in all laboratory work is accepted (student's level of achievement is not less than 60% or at least 60 points) only if all the laboratory work provided by the program of the discipline is performed and evaluated.

9.4.3 Integral level of student achievement in discipline

The integral level of student achievement in the mastery of discipline material as a whole is calculated as the weighted mean of the level of competence formation in lecture, practical and laboratory classes.:

$$IP = \sum_{i=1}^{n} \frac{(P_i \times T_i)}{T}, \ \%,$$

where – n number of types of training sessions;
P_i – level of achievements for the i-th type of occupation, %;
T_i – volume of the th type of occupation;
T – total volume of discipline.

Achievements of a student in mastering a certain discipline in general can not be evaluated positively if from any planned control measure in this discipline the student has not received a positive assessment..

If the level according to the results of any current control measure is higher than 60%, then the national scale is rated "credited".

If the level according to the results of any current control measure is lower than 60%, then the discipline is rated "Fx" and, if below 35%, then "F". On the national scale in this case, the "unrecorded" score is displayed.

10 THE STRUCTURE OF THE COMPLEX OF TEACHING AND METHODOLOGICAL PROVISION OF DISCIPLINE

The complex of teaching and methodological provision of discipline, should be located on the site of the department of system analysis and management and should contain:
1) work program of discipline;
2) educational content (information provision of lectures);
3) the task and methodical provision of laboratory work;
4) materials for methodological support of independent work of the student concerning:
– preliminary processing of information provision of lectures;
– solving self-control tasks for each topic
– performance of an individual task;
– preparation for the protection of individual tasks;
6) generalized tasks for the current control of the level of the formation of disciplinary competencies in the form of typical situational exercises with examples of solutions;
7) task for post-certification monitoring of the level of formation of disciplinary competencies.

11 RECOMMENDED BOOKS

11.1 Basic

1. Vasiliev F.P. Lectures on methods of solving extremal problems. - M .: Science. - 1974 - 376 p.
2. Fedorenko R.P. Approximate solution of optimal control problems. - M .: Science. - 1978 - 488 p.
3. Moiseev N.N. Elements of the theory of optimal systems. - Moscow: Nauka, 1971. - 562 p.
4. Fundamentals of the theory of optimal control. - M .: Higher school, 1990. - 432 p.
5. Egorov A.I. Optimal control of linear systems. - K .: Higher school, 1988. - 278 p.

6. Vasiliev F.P. Numerical methods for solving extremal problems. - M .: Science. - 1980 - 518 p.
7. Roytenberg Ya.N. Automatic control. - M .: Nauka, 1978.
8. Alekseev V.M., Tikhomirov V.M., Fomin S.V. Optimal control. - M .: Nauka, 1979.
9. Egorov A.I. Optimal control of thermal and diffusion processes. - M., Science, 1978.
10. Samarsky A.A, Mikhailov A.P. Mathematical modeling. Ideas Methods, Examples. - M .: Science. Fizmatlit, 1997. - 320 p.
11. Neiman Yu.I., Kogan N.Ya., Savelyev V.P. Dynamic control models. - M .: Science. Gl Editorial Board. Lit., 1985. - 400 c.
12. Differential Dynamic Models: Tutorial / B.I. Gerasimov, N.P. Puchkov, DN Protasov - Tambov: Publishing house GOU VPO TGTU, 2010. - 80 p

11.2 Auxiliary

1. Malafeev O.A., Muravyov A.I. Mathematical models of conflict situations and their resolution. Volume 1. General theory and auxiliary information. Publishing house SPBGU EIF SPb, 2000, 283p. Volume 2. Mathematical bases of modeling of processes of competition and conflicts in social and economic systems. Published by SPBGU EIF SPb, 2000, 294 p.

2. Malafeev O.A. Managed Conflict Systems. Publishing house of SPbGU, St. Petersburg, 2000, 276p.

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