# Syllabus of the educational component ED

Course name:	Optimal, adaptive and robust control systems
Level of higher education:	first (bachelor's)
Course page in Moodle:	https://dl2022.khadi-kh.com/course/view.php?id=2934
The amount of the educational	4 credits (120 hours)
component	
Final control form	test
Consultations:	According to schedule
Name of the department:	department of automation and computer-integrated
	technologies
Teaching language:	Ukrainian, English
Course leader:	Oleksandr Gurko, DrSci, professor
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## Optimal, adaptive and robust control systems

### Brief content of the discipline:

**The purpose** of the discipline is to form the student's knowledge of the basic methods of modern control theory.

**Subject:** pedagogically adapted system of concepts about the methods of modern automatic control theory.

#### The main tasks of the discipline are:

- studying the basic principles of optimal, adaptive and robust control theories;
- formation of skills to use modern software for the design of optimal, adaptive and robust automatic control systems.

#### Prerequisites for studying the discipline:

Higher mathematics; Physics; Automatic control theory.

#### Competencies acquired by the student:

#### General competencies:

Ability to apply knowledge in practical situations.

Ability to communicate in the state language both orally and in writing.

Skills in the use of information and communication technologies.

Ability to search, process and analyse information from various sources.

#### Special (professional) competencies:

Ability to solve practical problems using methods of mathematics, physics and electrical engineering.

Ability to analyse automation objects based on knowledge of the processes that occur in them and apply methods of automatic control theory to study, analyse and synthesize automatic control systems.

Ability to apply mathematical modelling, identification and numerical methods to develop mathematical models of individual elements and automation systems as a whole, to analyse the quality of their functioning using the latest computer technology.

Ability to freely use modern computer and information technologies to solve professional problems, program and use applied and specialized computer-integrated environments.

#### Learning outcomes according to the educational program:

Understand the essence of the processes occurring in automation objects and be able to analyse automation objects and justify the choice of structure, algorithms, and control schemes based on the results of the study of their properties. To be able to apply the methods of automatic control theory for the study, analysis, and synthesis of automatic control systems.

Be able to apply modelling, identification, and numerical methods to develop mathematical and simulation models of individual elements and automation systems as a whole, to analyse the quality of their functioning using the latest computer technology.

Be able to use a variety of specialized software to solve typical engineering problems in the field of automation.

Theme		Number of hours	
No	Name of themes (LEC, PW, SS	full-time	extramu ral
1	2	3	4
1	LEC. Models of dynamical systems in state space and their characteristics	2	
	PW. Simulation of systems in the state space using MATLAB	2	
	SS. Models of the system in state space in the form of a signal graph.	4	
2	LEC. Statement of the problem of optimal control. Criteria of optimality.	2	
2	SS. Fundamentals of calculus of variations. Lagrange problem and optimal control. Solution of variational problems in MATLAB.	10	
	LEC. Synthesis of a state controller. Ackermann's formula. The state observer design.	2	
3	PW. Design of the state controller in MATLAB. Design of the state observer in MATLAB.	2	
	SS. Design of the optimal system by the criterion of generalized work.	10	
	LEC. Dynamic Programming.	2	
4	PW. Implementation of the dynamic programming method in MATLAB	4	
	10		
	LEC. Optimal filters.	2	
5	PW. Optimal filters design in MATLAB.	2	
	SS. Stochastic optimal systems.	10	
	LEC Linear-quadratic regulator.	2	
6	PW. Design of linear-quadratic regulator in MATLAB	2	
0	SS. Linear-quadratic Gaussian regulator (LQG)	8	
	LEC. Robust systems.	2	
7	PW. H <sub>∞</sub> controller design in MATLAB.	2	
	SS. The use of PID controllers to provide the robustness of systems. $\mu$ -synthesis. Robust systems design using linear matrix inequalities.	18	
	LEC. Adaptive automatic control systems.	2	
8	PW. Simulation of the adaptive system in MATLAB.	2	
	SS. Self-adaptive systems. Adaptive systems with an identifier.	18	
	Lections	16	
Total	Practical works	16	
	Self-study	88	
Total fo	r course	120	

Theme plan	
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Individual educational and research task: not provided.

### Teaching methods:

1) verbal: 1.1 traditional: lectures, explanations, stories, etc.;

1.2 interactive (non-traditional): problem lectures, discussions, etc.;

2) visual: method of illustrations, method of demonstrations

3) practical: 3.1 traditional: practical classes, seminars.

### **Evaluation system and requirements:**

### **Current performance**

**1** The current success of applicants for the performance of educational types of work in training sessions and for the performance of independent work tasks is evaluated using a four-point rating scale with subsequent transfer to a 100-point scale. During the evaluation of the current academic performance, all types of work provided for by the educational program are taken into account.

**1.1** Lecture classes are evaluated by determining the quality of performance of specified tasks.

**1.2** Practical classes are evaluated by the quality of performance of a control or individual task, performance and design of practical work.

**1.3** Laboratory classes are evaluated by the quality of reports on the performance of laboratory work.

**1.4** Seminar classes are evaluated by the quality of individual assignment/abstract.

**2** The current performance of higher education applicants is assessed at each practical session (laboratory or seminar) on a four-point scale ("5", "4", "Z", "2") and entered in the journal of academic performance.

 – "excellent": the winner mastered the theoretical material flawlessly, demonstrates deep knowledge of the relevant topic or academic discipline, the main provisions;

- "good": the applicant has mastered the theoretical material well, has the main aspects from primary sources and recommended literature, presents it in a reasoned way; has practical skills, expresses his thoughts on certain problems, but certain inaccuracies and errors are assumed in the logic of the presentation of theoretical content or in the analysis of practical ones;

- "satisfactory": the applicant has basically mastered the theoretical knowledge of the educational topic or discipline, orients himself in primary sources and recommended literature, but answers unconvincingly, confuses concepts, answers additional questions uncertainly, does not have stable knowledge; when answering questions of a practical nature, reveals inaccuracy in knowledge, does not know how to evaluate facts and phenomena, connect them with the future profession;

- "unsatisfactory": the applicant has not mastered the educational material of the topic (discipline), does not know scientific facts, definitions, hardly orients himself in primary sources and recommended literature, lacks scientific thinking, practical skills are not formed.
 3 The final score for the current activity is recognized as the arithmetic mean sum of points for each lesson, for individual work, current test works according to the formula:

$$K^{current} = \frac{K1 + K2 + \dots + Kn}{n},$$

where  $K^{current}$  is the final assessment of success based on the results of current control; K1, K2, ..., Kn – evaluation of the success *n* of the current control measure;

n - the number of measures of current control.

Assessments are converted into points according to the calculation scale (table 1).

4-point scale	100 points scale	4-ball scale	100 points scale	4-ball scale	100 points scale	4-ball scale	100 points scale
5	100	4.45	89	3.90	78	3.35	67
4.95	99	4.4	88	3.85	77	3.3	66
4.9	98	4.35	87	3.80	76	3.25	65
4.85	97	4.3	86	3.75	75	3.2	64
4.8	96	4.25	85	3.7	74	3.15	63
4.75	95	4.20	84	3.65	73	3.1	62
4.7	94	4.15	83	3.60	72	3.05	61
4.65	93	4.10	82	3.55	71	3	60
4.6	92	4.05	81	3.5	70	from 1.78 to 2.99	from 35 to
							59
						reassen	nbly
4.55	91	4.00	80	3.45	69	from 0 to 1.77	from 0 to 34
4.5	90	3.95	79	3,4	68	repeated	study

 Table 1 – Recalculation of the average grade for the current activity into a multi-point scale

#### **Final assessment**

1 The exam is held after studying all topics of the discipline and is completed by students of higher education during the examination session after the end of all classroom classes2 Students of higher education who have completed all types of work prescribed by the curriculum in the discipline are admitted to the exam:

- were present at all classroom classes (lectures, seminars, practical);

- completed all missed classes on time;

- scored the minimum number of points for the current academic performance (at least 36 points, corresponding to the national scale "3");

If the current success in the discipline is lower than 36 points, the higher education applicant has the opportunity to increase his current point to the minimum before the beginning of the examination session.

**3** Assessment of the knowledge of applicants when taking the exam is carried out on a 100-point scale.

Assessment of the knowledge of applicants through testing is carried out according to the following scale:

- "Excellent": at least 90% of correct answers;

- "Very good": from 82% to 89% of correct answers;

- "Good": from 74% to 81% of correct answers;

- "Satisfactory": from 67% to 73% of correct answers;

- "Satisfactory enough": from 60% to 66% of correct answers;

- "Unsatisfactory": less than 60% of correct answers.

**4** The final grade for the academic discipline is defined as a weighted average grade that takes into account the overall grade for the current academic performance and the grade for passing the exam.

**5** The calculation of the overall final grade for the study of an academic discipline is carried out according to the formula:

$$PK^{fin} = 0, 6 \cdot K^{current} + 0, 4 \cdot E$$

where  $PK^{fin}$  is the final assessment of success in disciplines, the form of final control for which is an exam;

 $K^{current}$  – final assessment of success based on the results of current control (on

a 100-point scale);

*E* - grade based on the results of the exam (on a 100-point scale).

0.6 and 0.4 are coefficients for the ratio of points for current success and passing the exam.

**6** For performing individual independent work and participation in scientific events, additional points are awarded to the winners.

6.1 Additional points are added to the sum of points scored by the student of higher education for the current educational activity (for disciplines for which the final form of control is a test), or to the final grade in the discipline for which the final form of control is an exam.6.2 The number of additional points awarded for different types of individual tasks depends on their volume and importance:

- prizes in the discipline at the international / all-Ukrainian competition of scientific student works - 20 points;

- prize places in the discipline at the all-Ukrainian Olympiads - 20 points;

- participation in the international / all-Ukrainian competition of scientific student works - 15 points

 participation in international / all-Ukrainian scientific conferences of students and young scientists - 12 points;

- participation in all-Ukrainian Olympiads in the discipline - 10 points

- participation in olympiads and scientific conferences of the KhNAHU in the discipline - 5 points;

- performance of individual scientific and research (educational and research) tasks of increased complexity - 5 points.

**6.3** The number of additional points cannot exceed 20 points.

**7** The total final grade for studying an academic discipline cannot exceed 100 points.

The overall final grade for the study of the academic discipline is determined according to the scale given in Table 2.

Score	Evaluation	n on a		ECTS scale		
points	national scale		Rating	Criteria		
	examination	test				
90-100	Perfectly	Passed	A	The theoretical content of the course has been mastered in its entirety, without gaps, the necessary practical skills for working with the mastered material have been formed, all educational tasks provided for in the training program have been completed, the quality of their performance has been assessed with a number of points close to the maximum		
80–89	Good	Passed	В	The theoretical content of the course has been mastered in its entirety, without gaps, the necessary practical skills for working with the mastered material have mainly been formed, all educational tasks provided for by the training program have been completed, the quality of most of them has been assessed with a number of points close to the maximum		

**Table 2** – The scale for evaluating the knowledge of the students based on the results of the final control of the academic discipline

Score	Evaluation	n on a	ECTS scale		
in	national scale		Rating	Criteria	
points	examination test		0		
75-79			WITH	The theoretical content of the course has been mastered in its entirety, without gaps, some practical skills of working with the mastered material have not been formed enough, all educational tasks provided for by the training program have been completed, the quality of none of them has been assessed with a minimum number of points, some types of tasks have been completed with errors	
67-74	actorily		D	The theoretical content of the course is partially mastered, but the gaps are not of a significant nature, the necessary practical skills for working with the mastered material are basically formed, most of the educational tasks provided by the training program have been completed, some of the completed tasks may contain errors	
60–66	Satisf		E	The theoretical content of the course has been partially mastered, some practical work skills have not been formed, many educational tasks provided by the training program have not been completed, or the quality of some of them has been assessed with a number of points close to the minimum.	
35–59	Unsatisfactorily	passed	FX	The theoretical content of the course has been partially mastered, the necessary practical work skills have not been formed, most of the prescribed training programs of educational tasks have not been completed, or the quality of their implementation has been assessed with a number of points close to the minimum; with additional independent work on the course material, it is possible to improve the quality of the performance of educational tasks (with the possibility of retaking)	
0–34	Unacceptable	Not	F	The theoretical content of the course has not been mastered, the necessary practical work skills have not been formed, all completed educational tasks contain gross errors, additional independent work on the course material will not lead to any significant improvement in the quality of the performance of educational tasks (with a mandatory repeat course)	

**Course policy:** – the course involves working in a team, the environment in the classroom is friendly, creative, open to constructive criticism;

- mastering the discipline involves mandatory attendance of lectures and practical classes, as well as independent work;

- independent work involves the study of individual topics of the academic discipline, which are presented in accordance with the program for independent study, or were considered briefly;

- all tasks provided by the program must be completed within the set time;

- if the student of higher education is absent from classes for a good reason, he presents the completed tasks during independent preparation and consultation of the teacher;

- the coursework must be protected no later than a week before the beginning of the examination session;

- while studying the course, students of higher education must comply with the rules of academic integrity set forth in the following documents: "Rules of academic integrity of participants in the educational process of the KhNAHU" (https://www.khadi.kharkov.ua/fileadmin/P\_Standart/pologeniya/stvnz\_67\_01\_dobroch\_1.p df), "Academic integrity. Checking the text of academic, scientific and qualification papers for

(<u>https://www.khadi.kharkov.ua/fileadmin/P\_Standart/pologeniya/stvnz\_85\_1\_01.pdf</u>), "Moral and ethical code of participants in the educational process of the KhNAHU (<u>https://www.khadi.kharkov.ua/fileadmin/P\_Standart/pologeniya/stvnz\_67\_01\_MEK\_1.pdf</u>). - in case of detection of plagiarism, the applicant receives 0 points for the task and must

repeat the tasks provided for in the syllabus; - writing off during tests and exams is prohibited (including using mobile devices). Mobile

devices are allowed to be used only during online testing.

#### **Recommended Books:**

1. Gu D.-W., Petkov P. H., and Konstantinov M.M. Robust control design with MATLAB, 2nd ed., Springer Science & Business Media. 2013. 490 p.

2. Zhou, K., J. C. Doyle, K. Glover. Robust and optimal control, Prentice Hall. 1996. 586 p.

3. Richard C., Dorf, and Robert H. Bishop. Modern control systems. Pearson Prentice Hall, 2008.

4. Nagrath I. J., Gopal M. Control Systems Engineering. 6th edition. New age international publishers, 2017.

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