MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aviation University
Faculty of Air Navigation, Electronics and Telecommunications
Department of Aviation Computer-Integrated Complexes

AGREED

Dean of Faculty of Air Navigation,
Electronics and Telecommunications

_____ Sergey ZAVGORODNYI

"___"_____ 2022

APPROVED

Vice-Rector for Academics

_____ Anatolii POLUKHIN

"___"_____ 2022

Quality management system

EXTENDED PROGRAM
on
«Optimal Control Systems»

Educational Professional Program: "Computer-Integrated Technological Processes and Production"

Field of study: 15 «Automation and Instrumentation»

Specialty: 151 «Automation and Computer-Integrated Technologies»

Training Form	Seme-ster	Total (hours/credits ECTS)	Lec-tures	Pract. classes	Lab. classes	Self-study	HT/ CGP/ CW	TP/CP	Semester Grade
Day Form	2	120/4,0	18	-	18	84	-	-	Graded test –2 s

Index CM - 2 - 151 - 2 / 21 - 3.4

QMS NAU EP 22.01.09 – 01 – 2022

The Extended Program on «Optimal Control Systems» is developed on the basis of the Educational Professional Program «Computer-integrated technological processes and production», Curriculum and Extended Curriculum of Education Seekers Training for «Master» CM - 2 - 151 - 2/21 and ECM - 2 - 151 - 2/21 for the Specialty 151 "Automation and Computer-Integrated Technologies" and corresponding normative documents

Developed by:
Professor of Aviation
Computer-Integrated Complexes Department _____ Olexander ABLESIMOV

Discussed and approved by the Graduate Department for Specialty 151 «Automation and Computer-Integrated Technologies», Educational Professional Program «Computer-integrated technological processes and production» – Aviation Computer-Integrated Complexes Department, Minutes № __ of « » _____2022.

Guarantor
of the Educational and Professional Program _____ Mykola FILIASHKIN

Head of the Department   _____   Victor SINEGLAZOV

The Extended Program was discussed and approved by the Scientific-Methodical-Editorial Board of the Faculty of Air Navigation, Electronics and Telecommunications, Minutes №___ as of «___» _____ 2022

Head of the SMEB   _____   Olexander KRYVONOSENKO

Vice Rector on International
Collaboration and Education

_____ Iryna ZARUBINSKA

"___"_____ 2022

Document level – 3b
The Planned term between revisions – 1 year
Master copy

CONTENT

INTRODUCTION

The Extended Program on «Optimal Control Systems» is developed on the basis of "Methodical instructions for the development and design of the Extended Program for the subject", enacted by the order as of 29.04.2021 № 249/од and corresponding normative documents.

1. EXPLANATORY NOTE

1.1. Place, objectives, tasks of the subject.

The place of the subject «Optimal Control Systems» in the system of professional training**.**

The educational subject refers to the disciplines of free choice of students. The discipline is the theoretical basis of the set of knowledge and skills that form the profile of a specialist in the field of automation and computer-integrated technologies.

The aim of teaching the discipline is to create a complex of knowledge on the synthesis of optimal control systems, as well as control and operation of modern optimal control systems as part of computer-integrated complexes.

Tasks of the discipline are:
- formation of stable knowledge on methods of synthesis of optimal management systems and methods of quality analysis of management processes and correction of dynamic properties of systems;
- formation of practical skills in designing and using optimal management systems.

1.2. Learning outcomes the subject makes it possible to achieve.

The study of the academic discipline involves the formation of the following program learning outcomes in the applicants:
- to design, modify and research optimal computer-integrated control systems;
- analyze the structure and algorithms of optimal management systems.

1.3. Competences the subject makes it possible to acquire.

As a result of studying this discipline, the student acquires the following **program competencies**:
- 3K2 - the ability to generate new ideas (creativity);
- CK3 - the ability to apply modeling and optimization methods to research and improve the efficiency of systems and processes of managing complex technological and organizational-technical objects in aviation;
- CK6 - the ability to apply problem-oriented methods of analysis, synthesis and optimization of automation systems, cyber-physical productions, processes of managing technological complexes.

1.4. Interdisciplinary connections.

The educational discipline «Optimal Control Systems» is based on the knowledge of such disciplines as «Methods of Modeling and Optimization of Systems and Processes», «Applied Identification Theory» and interacts with the discipline «Algorithmic and Information Support of Computer-Integrated Systems», which are studied in parallel with it and complement each other one.

2. COURSE TRAINING PROGRAM ON THE SUBJECT.

2.1. The subject content

The educational material of the subject «Optimal Control Systems» is structured on a modular principle and consists of two educational modules, namely:

- educational **module No. 1 "Methodological foundations of optimal control systems"**;

- educational **module No. 2 "Methods of dynamic optimization of control"**, each of which is logically complete, independent and integral part of the curriculum. Its mastering has in view module test and analysis of its completion.

2.2. Modular structuring and integrated requirements for each module

Module No. 1 "Methodological foundations of optimal control systems"

Integrated requirements of module No 1:

Know:
- algebraic criteria in management problems and static optimization.

Be able:
- perform synthesis of limited controls for autonomous systems.

Topic 1. **Introduction to the theory of optimal management**

Introduction to the theory of optimization and optimal control. Classification of optimal control systems. Static and dynamic optimization. General formulation of the problem of optimal management. Optimality criteria. Theoretical and functional restrictions on state and control vectors.

Topic 2. **Algebraic criteria in management problems**

Controllability of linear non-stationary systems. Area of reach. Controllability criterion. Controllability of linear stationary systems. Observability and identifiability of linear systems. Observers. The principle of duality of management and monitoring tasks. Problems of synthesis of limited controls for autonomous systems. Management of linear systems with incomplete measurements.

Topic 3. **Static optimization**

Methods of finding the unconditional extremum of the optimality criterion. Minimum necessary and sufficient conditions. Methods of conditional optimization in the presence of autonomous constraints-inequalities and constraints of the type of connections. Multi-criteria optimization. Pareto set. Schemes of compromises.

Module No. 2 "Methods of dynamic optimization of control"

Integrated requirements of module No 2:

Know:
- methods of dynamic optimization.

Be able:
- perform synthesis of optimal control algorithms.

Topic 1. **Variational methods of dynamic optimization**

Necessary and sufficient conditions for the minimum functional. Conditions of transversality. Generalization of the problem of unconditional optimization for the case of many variables. Application of variational calculus methods to optimal control problems. Linear optimal control. Optimal control with a generalized quality indicator.

Topic 2. **Pontryagin's maximum principle in optimal control problems**

Hamilton's function. Optimality conditions in the Pontryagin form are necessary. Maximum control system speed. Determination of strategy and optimal control algorithm. The impact of disturbances and inaccuracies in the assignment of object parameters on the quality and stability of high-speed systems.

Topic 3. **Dynamic programming method in control tasks**

Bellman's principle of optimality. Minimum error function. Bellman's functional and differential equation. Synthesis of optimal control algorithms by the method of dynamic programming.

Topic 4. **Analytical design of optimal control systems**

Formulation of problems of analytical design of an optimal regulator. The Letov-Kalman method. The Letov-Kalman theorem. O. A. Krasovsky's method. O. A. Krasovsky's theorem.

2.3. Training schedule of the subject.

№	Topic	Academic hours			
		Total	Lectures	Lab. classes	Self-study
Module №1 «Methodological foundations of optimal control systems»					
1.1	Introduction to the theory of optimal control	**2 semester**			
		14	2	2	10
1.2	Algebraic criteria in control problems	20	2 2	2	14
1.3	Static optimization	16	2	2	12
1.4	Module test 1	6	-	2	4
Total for Module 1		**56**	**8**	**8**	**40**
Module №2 «Methods of dynamic optimization of control»					
2.1	Variational methods of dynamic optimization	14	2	2	10
2.2	Pontryagin's maximum principle in optimal control problems	16	2 2	2	10
2.3	Dynamic programming method in control tasks	14	2	2	10
2.4	Analytical design of optimal control systems	14	2	2	10
2.5	Module test 2	6	-	2	4
Total for Module 2		**64**	**10**	**10**	**44**
Total for the discipline		**120**	**18**	**18**	**84**

3. BASIC CONCEPTS OF GUIDANCE ON THE SUBJECT

3.1. Teaching methods

Both subject-oriented and individually-oriented learning technologies are used to activate the educational and cognitive activity of students during the study of the discipline. Laboratory work mainly uses the Case Study method, and lectures and presentations and interactive learning technologies are used.

3.2. List of references

Basic literature

3.2.1. Тунік А.А., Абрамович О.О. Основи сучасної теорії управління. Навчальний посібник. – К.: Видавництво Національного авіаційного університету «НАУ-друк», 2010. – 260 с.

3.2.2. Конспект лекцій «Сучасна теорія управління, методи синтезу та оптимізації управління» / Успенський В.Б., Шипуліна Л.В. - Х.: НТУ "ХПІ", 2013. — 136 с.

3.2.3. Тютюнник А. Г. Оптимальні та адаптивні системи автоматичного керування: навчальний посібник для студ. вузів. - ЖІТІ. – Житомир, 2002.

3.2.4. Desineni Subbaram Naidu. Optimal control systems. – Boca Raton, Fla. : CRC Press, 2003. – 433 р.

3.2.5. Lawrence C. Evans. An Introduction to Mathematical Optimal Control Theory. – Berkeley: University of California, 2010. – 126 р.

Additional literature

3.2.6. Соколов С. В. Оптимальні та адаптивні системи : навчальний посібник / Суми : Сумський державний університет, 2018. –221 с.

3.2.7. Бабак В. П., Синєглазов В. М., Таранов С. Г. Самоналагоджувальні інформаційні системи - Київ: НАУ, 2007 - 152с.

3.2.8. Мокін Б.І., Мокін О.Б. Теорія автоматичного керування. Методологія та практика оптимізації /Навчальний посібник, Вінниця: ВНТУ, 2013, 210 с.

3.3 Information resources on the Internet

3.3.1 http://www.infra.kth.se/~soh/decisiontheory

3.3.2 https://moluch.ru/archive/125/34485/

3.3.3 http://www.prorobot.ru/nauka/expert

4. RATING SYSTEM OF KNOWLEDGE AND SKILLS ASSESSMENT

4.1. Assessment of certain types of academic work performed by the student is carried out in points in accordance with table 4.1.

Table 4.1

Type of Academic Work	Maximum Grade Values	Type of Academic Work	Maximum Grade Values
Semester №2			
Module №1 «Methodological foundations of optimal control systems»		**Module № 2** «Methods of dynamic optimization of control»	
Execution and defending laboratory works (total)	$7б×3 = 21$	Execution and defending laboratory works (total)	$7б×3 = 21$
Execution of tasks of express control under time of laboratory classes	$5б×3 = 15$	Execution of tasks of express control under time of laboratory classes	$5б×3 = 15$
For carrying out module test №1, a student must receive not less than	22	*For carrying out module test №2, a student must receive not less than*	22
Module Test №1	14	Module Test №2	14
Total for the Module 1	50	**Total for the Module 2**	50
		Total for modules 1, 2	**100**
		Total for the subject	**100**

The credit rating is determined (in points and on a national scale) based on the results of all types of educational work during the semester.

4.2. The kind of academic work, performed by a student, has been passed, if a student got positive grade.

4.3. The grades a student has been given for the different kinds of academic work the summed up and the result constituting a Current Module Grade is entered into the Module Grade Register.

4.4. In the case of **Graded test**, the sum of the final semester module grade in points constitutes the final semester rating grade, which is converted into a grade based on the national scale and the ECTS scale.

4.5. The Total Semester Grade is entered into the credit and examination information, the study card and into the student's record book, for example: ***92/Ex/A, 87/Good/B, 79/Good/C, 68/Sat/D, 65/Sat./E***, etc.

4.6. The Total Subject Grade corresponds to the Total Semester Grade. The Total Subject Grade is entered in the Diploma Supplement.

(Ф 03.02 – 01)

АРКУШ ПОШИРЕННЯ ДОКУМЕНТА

№ прим.	Куди передано (підрозділ)	Дата видачі	П.І.Б. отримувача	Підпис отримувача	Примітки

(Ф 03.02 – 02)

АРКУШ ОЗНАЙОМЛЕННЯ З ДОКУМЕНТОМ

№ пор.	Прізвище, ім'я, по батькові	Підпис ознайомленої особи	Дата ознайом-лення	Примітки

(Ф 03.02 – 04)

АРКУШ РЕЄСТРАЦІЇ РЕВІЗІЇ

№ пор.	Прізвище, ім'я, по батькові	Дата ревізії	Підпис	Висновок щодо адекватності

(Ф 03.02 – 03)

АРКУШ ОБЛІКУ ЗМІН

№ зміни	№ листа (сторінки)				Підпис особи, яка внесла зміну	Дата внесення зміни	Дата введення зміни
	Зміненого	Заміненого	Нового	Анульо-ваного			

(Ф 03.02 – 32)

УЗГОДЖЕННЯ ЗМІН

	Підпис	Ініціали, прізвище	Посада	Дата
Розробник				
Узгоджено				
Узгоджено				
Узгоджено				