National technical university of Ukraine
«IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE»

DEPARTMENT OF SPACE ENGINEERING

THEORY OF AUTOMATIC CONTROL

Syllabus

General information	
Level of higher education	***The first (Bachelor)***
Field of knowledge	*13 Mechanical engineering*
Specialty	*134 Aerospace and rocket-space technology*
Educational program	*Aerospace and rocket systems engineering*
Discipline status	*Normative*
Form of education	*Full-time (daytime)*
Year of study, semester	*2 course, spring semester*
Scope of discipline	*5 credits /150 hours, lectures (36 hours), practical classes (18 hours), laboratory works (18 hours), independent work (78 hours)*
Semester control	*Exam / test work, control works*
Schedule	*In accordance to http://rozklad.kpi.ua*
Language of teaching	*English*
Teacher information	Lecturer: *candidate of technical sciences, Associate professor, Pysarets Anna, anna.v@ukr.net* Practical classes: *candidate of technical sciences, Associate professor, Pysarets Anna* Laboratory works: *candidate of technical sciences, Associate professor, Pysarets Anna*
Course placement	Google Classroom

Academic discipline program

Description of the academic discipline, its purpose, subject of study and learning outcomes

The purpose of the discipline *is training of highly qualified specialists in the theory of automatic control.*

Discipline subject *are fundamental concepts, definitions and principles of automatic control theory, control schemes and models, methods for analyzing automatic control systems in the time and frequency domains, which contributes to the accumulation of knowledge about the laws and properties of control processes for technical objects, regardless of their physical nature.*

Professional competencies *that the student will receive when studying the discipline are*

- ability to use the theory of flight dynamics and control at designing of aerospace and rocket-space technology (PC 1);
- ability to design and test the components of aircraft and rocket and space technology, its equipment, systems and subsystems (PC 5);
- skills to use information and communicative technologies and specialized software in studying and professional activity (PC 7);
- skills to use integral technologies of computer design and modeling of aircraft and rocket and space systems and elements (PC 14).

Program results of learning *are*

- understand the structure and principles of operation of onboard and navigation equipment of aircraft and rocket and space technology (PRL 7);
- calculate the power plants of rockets and space vehicles: pulse engines, gas and gas turbine engines, flywheel engines, liquid and solid fuel rocket engines, solar batteries, generators, servo motors (PRL 12);
- apply modern methods of modeling, design and manufacturing of aircraft and rocket and space elements and systems (PRL 18);
- explain the influence of structural parameters of rocket and space vehicles on their performance. Know methods of stability and controllability of aircraft and rocket and space technology (PRL 22).

Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of training in the corresponding educational program)

The discipline is taught on the basis of the application of theoretical knowledge and practical skills that were obtained by students earlier in the study of a number of fundamental disciplines ("Higher Mathematics", "Physics", "Electrical Engineering" and others).

The knowledge and skills gained in the study of this discipline are used to study the disciplines of vocational learning.

The content of the discipline

Section 1. Basic concepts and definitions in the control theory.
Topic. Basic concepts and definitions in the control theory.

Section 2. Characteristics of dynamic elements.
Topic 1. Time responses.
Topic 2. Frequency responses.
Topic 3. Typical dynamic elements and their characteristics.

Section 3. Mathematical description of control systems.
Topic 1. Construction of initial differential equations of automatic control systems.
Topic 2. Transfer functions of automatic control systems.
Topic 3. Application of block diagrams. Multi-loop control systems.

Section 4. Automatic control systems stability.
Topic 1. Algebraic stability criteria.
Topic 2. Frequency stability criteria.

Section 5. Quality and accuracy of control systems.
Topic 1. Quality of control systems.
Topic 2. Root method. Frequency quality criteria.
Topic 3. Accuracy of control systems in typical modes.
Topic 4. Methods for improving the control systems accuracy.

Section 6. Improving the quality of the regulatory process.
Topic 1. Correcting devices. Methods for increasing the stability margin.

Section 7. Methods of control systems synthesis.
Topic 1. Methods of control systems synthesis.

Learning Materials and Resources

Basic literature

1. William Bolton, Instrumentation and control systems. Third edition. Elsevier, Newnes.
2. Norman S. Nise, Control systems engineering. California State Polytechnic University, Pomona. – Seventh edition.

Additional literature

1. *Dorf Richard C., Bishop Robert H. Modern control systems. 12th ed. Prentice Hall, 1082 p.*
2. *Golnaraghi F., Kuo Benjamin C. Automatic Control Systems. 9th edition. John Wiley & Sons. Inc.*

Educational content

Methodology for studying the discipline (educational component)

Lectures, practical classes and laboratory works are provided for studying the discipline.

5.1. Lectures

Nr	The lecture topic and main questions list
1	***Section 1. Basic concepts and definitions in the control theory.*** ***Topic. Basic concepts and definitions in the control theory.*** *General information about automatic control systems. Classification of control systems. Programs and laws of regulation. Control principles.*
2	***Section 2. Characteristics of dynamic links.*** ***Topic 1. Time characteristics.*** *General concepts of dynamic links. Typical dynamic links. Link transfer function. Time responses of dynamic links.* ***Topic 2. Frequency characteristics.*** *Frequency transfer function and frequency responses of control systems elements.* *Logarithmic frequency responses of control systems elements.* ***Topic 3. Typical dynamic links and their responses.*** *Position elements and their responses. Integrating and differentiating elements and their responses.*
3	***Section 3. Mathematical description of control systems.*** ***Topic 1. Construction of initial differential equations of automatic control systems.*** *Mathematical models of physical systems.* ***Topic 2. Transfer functions of automatic control systems.*** *The transfer function determination of an open-loop system. The transfer functions of a closed-loop system with respect to input and external disturbances. The system transfer function by error.* ***Topic 3. Application of block diagrams. Multi-loop control systems.*** *Block diagrams. Typical element connections. Block diagram transform. Control systems transfer functions.*
4	***Section 4. Automatic control systems stability.*** ***Topic 1. Algebraic stability criteria.*** *Concept of control systems stability (concept of stability criteria, characteristic equation, characteristic equation roots, stability limits). Hurwitz stability criterion. Examples of problem solving.* ***Topic 2. Frequency stability criteria.*** *Mikhailov stability criterion. Examples of problem solving. Nyquist stability criterion. Determination of control systems stability by logarithmic frequency characteristics. Stability margins.*
5	***Section 5. Quality and accuracy of control systems.*** ***Topic 1. Quality of control systems.*** *The concept of control systems quality. Quality characteristics of automatic control systems.* ***Topic 2. Root criteria of quality. Frequency quality criteria.*** *Root quality indicators. Frequency method for transient process quality analysis.*

	Topic 3. Accuracy of control systems in typical modes. *Steady-state error. Test input signals. Definition of the steady-state error with respect to system configuration.* ***Topic 4. Methods for improving the control systems accuracy.*** *Usage of isodromic devices. Regulation by derivatives of the error. Use of non-unit feedbacks.*
6	***Section 6. Improving the quality of the regulatory process.*** ***Topic. Correcting devices. Methods for increasing the stability margin.*** *Systematic correcting devices. Parallel correcting devices.*
7	***Section 7. Methods of control systems synthesis.*** ***Topic 1. Methods of control systems synthesis.*** *Root methods. Method of logarithmic amplitude characteristics. Synthesis of automatic control systems based on frequency quality criteria.*

5.2. Practical classes

The main objectives of the cycle of practical training are to consolidate the theoretical provisions of the discipline and the acquisition of skills and experience in their practical application.

Nr	*Lesson topic*
1	*Mathematical models of physical systems. Construction of dynamics equations of control systems elements.*
2	*Determination of transfer functions of control systems elements.*
3	*Time responses of control systems elements.*
4	*Block diagram transform. Determination of control systems transfer functions.*
5	*Control system stability by algebraic criteria.*
6	*Control system stability by frequency criteria.*
7	*Evaluation of the transient processes quality.*
8	*Accuracy of control systems in typical modes.*

5.3. Laboratory works

The main tasks of the laboratory works cycle are the acquisition of skills in mathematical software, the study of the methodology for modeling dynamic systems and their elements, methods for obtaining time and frequency responses of dynamic systems, assessing and analyzing the capabilities of the system based on simulation results.

Nr	*Work topic*	*Number of classroom hours*
1	***Basics of modeling automatic control systems in MatLab.*** ***Purpose of the work*** *is to study the library of SimuLink expansion blocks of the MatLab system; methodology for creating models using SimuLink; consider the settings and assignments for signal source blocks (Sources section) and signal receivers (Sinks section); explore the parameters of standard input signals; test the technique of combining standard signals into a single vector signal.*	*2*
2	***Investigation of time responses for standard dynamic elements.*** ***Purpose of the work*** *is learn to plot graphs of dynamic element time responses; determine the parameters of the transient process; investigate the influence of transfer function parameters on the transient process.*	*5*
3	***Determination of frequency responses for standard dynamic elements.*** ***Purpose of the work*** *is to learn determine the frequency transfer function from the transfer function of an dynamic element; investigate the*	*5*

	methodology for constructing the frequency responses of a dynamic element; obtain the frequency responses of first and second order elements.	
4	***Investigation of control system stability.*** ***Purpose of the work*** *is to evaluate the stability of a control system by various criteria.*	*3*
5	***Evaluating of stability margins for control system.*** ***Purpose of the work*** *is learning to determine the stability margins of a system using Bode and Nyquist diagrams.*	*3*

Student's independent work

6.1. In preparing for the lecture, it is necessary to read the materials of the previous lecture.

6.2. Preparing for laboratory work requires familiarization with the theoretical materials given in the protocol. After completing the work, it is necessary to draw up a protocol of the studies, write down the conclusions for each task and answer the control questions presented in the protocol.

6.3. Preparing for a practical lesson involves working with notes on the topic and completing an individual task.

Self-study of students involves study of issues that arise when studying the relevant sections of the course on their own.

78 hours are allocated for self-study of students and 36 hours of them are for preparing for the exam.

Table of time distribution for independent work of a student

The name of the topic that is submitted for self-study	*Number of hours for self-study of a student*
1	*2*
1. Preparing for lectures, practical exercises and laboratory work	*38*
2. Preparing a modular test	*4*
3. Exam preparing	*36*
Total	***78***

Politics and control

Policy of academic discipline (educational component)

- *class attendance is mandatory;*
- *in practical classes it is necessary to take an active part in problems solving;*
- *the defense of laboratory work is carried out by performing tasks similar to those of laboratory work (which confirms the student's mastery of certain techniques and algorithms) and by questioning based on lecture materials that correspond to the topic of the work;*
- *the student receives incentive points for active participation in the educational process (timely completion and defense of laboratory work, problems solving during practical classes).*

Types of control and rating system for assessing learning outcomes (RSO)

A student's rating by discipline consists of the points had been receiving for completing

1) *individual tasks in practical classes;*
2) *performance and defense of laboratory works;*

3) *preparing of modular control work.*

Scoring Criteria

The practical lesson is estimated at 4 points:

- *full answer (at least 90% of the required information) - 4 - 2.8 points;*
- *a fairly complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 3 points;*
- *incomplete answer (at least 60% of the required information) and minor errors - 2 points;*
- *passive work – 0 points.*

The maximum number of points for work in practical classes is 4 points $\times 7 = 28$ *points.*

Laboratory work

- *impeccable work – 4 points (2 points for the performance of the work and 2 points for the defence of the work);*
- *if there are some shortcomings in the preparing and / or performance of work - 1.5 points;*
- *the work is not completed or not defenced - 0 points.*

The maximum number of points for performing and defending laboratory work is

$$4 \text{ points} \times 5 = 20 \text{ points.}$$

The modular test work is evaluated at 12 points according to the following criteria:

- *full answer (at least 90% of the required information) - 12 – 11 points;*
- *a fairly complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 10 – 9 points;*
- *incomplete answer (at least 60% of the required information) and minor errors – 8 – 7 points;*
- *the answer does not meet the requirements for "satisfactory" – 0 points.*

Calculation of the rating scale (R):

The sum of control measures points during the semester (semester component R_S) is

$$R_S = 4 \times 7 + 4 \times 5 + 12 = 60 \text{ points.}$$

The rating scale for the discipline is

$$R = R_S + R_E = 60 + 40 = 100 \text{ points.}$$

Where, R_E is exam component.

Calendar control: held twice a semester as a monitoring of the current state of fulfilments of the syllabus requirements.

The condition of the first attestation is to receive at least 9 points. The condition of the second attestation is to receive at least 28 points.

Semester control: exam.

Conditions for admission to semester control are defence of all laboratory works, a positive assessment for the implementation of the module control work, a semester rating of more than 35 points.

During the exam, the student performs a written control work. Each task contains three theoretical questions and one practical one. Each question is worth 10 points.

Question scoring system:

- *full answer (at least 90% of the required information) - 10 – 9 points;*
- *a fairly complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 8 – 7 points;*
- *incomplete answer (at least 60% of the required information) and minor errors – 6 points;*
- *the unsatisfactory answer – 0 points.*

The sum of starting marks and marks for the examination paper is converted into an examination grade in accordance with the table.

Correspondence table of rating points to assessments on the university scale:

Number of points	***Grade***
100-95	Excellent
94-85	Very good
84-75	Good
74-65	Satisfactorily
64-60	Enough
Less than 60	Unsatisfactorily
The conditions for obtaining a grade are not met	Not allowed

The working program of the academic discipline (syllabus):

Composed by associate professor, candidate of technical sciences, Anna Pysarets

Accepted by *department* of space engineering (protocol № 15 from 07.06.2023).

Agreed by the Methodological Commission of ER IAT (*protocol* № 6 from 22.06.2023).