NATIONAL UNIVERSITU OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE

Department of Machine and Equipment Design

" **REVIEWED**
at the meeting of the Faculty of Design and Engineering

"____"_____20__ p.

CURRICULUM OF ACADEMIC DISCIPLINE
Calculation and design of robots and manipulators

Area of knowledge 13 "Mechanical Engineering"
Specialty 133 "Sectoral mechanical engineering"
Academic programme «Sectoral mechanical engineering»
Faculty Sectoral mechanical engineering
Developed by: Ph.D Oleksandr SPODOBA

Kyiv – 2026

Description of the discipline Calculation and design of robots and manipulators

(до 1000 друкованих знаків)

The objective of the discipline is to teach students to draw up calculation schemes, determine the stability and strength of parts, robots and manipulators, as well as the structural shapes and dimensions of robot and manipulator elements.

Academic degree, specialty, academic programme		
Academic degree	Bachelor	
Specialty	13 "Mechanical engineering"	
Academic programme	Sectoral mechanical engineering	
Характеристика навчальної дисципліни		
Type	selective	
Total number of hours	360	
Number of ECTS credits	10,0	
Number of modules	4	
Course project (work) (if any)	Course project (work) 30	
Form of assessment	credit / exam	
Indicators of the discipline for full-time and part-time forms of university study		
	Full-time	**Part-time**
Year of study	4	-
Semester	7; 8	-
Lectures	56 hours.	-
Practical classes and seminars	–	-
Laboratory classes	56 hours.	-
Self-study	158 hours.	-
Number of hours per week for fulltime students	4 hours	-

1. Purpose, competencies and program results of the academic discipline

Purpose: students must learn to apply general scientific provisions on the calculation and design of mechanical systems of robots and manipulators, mechanisms and equipment in the conditions of installation, operation, and aggregation of working machines with hydraulic drive, pneumatic drive, electric drive and design elements of automatic regulation of continuous technological processes of modern agricultural production.

List of academic disciplines that precede the study of "Calculation and design of robots and manipulators" (if available)

OK12 Materials science
OK13 Construction technology
OK19 Machine parts and PTM

Acquisition of competences:

Integral competence (IC):

The ability of a person to solve complex specialized tasks and practical problems in a certain field of professional activity or in the process of learning, which involves the application of certain theories and methods of relevant sciences and is characterized by the complexity and uncertainty of conditions.

General competencies (GC):

GC2. The ability to apply knowledge in practical situations.

GC3. The ability to plan and manage time.
GC4. The ability to search, process and analyze information from various sources.
GC5. The ability to generate new ideas (creativity).
GC8. The ability to act socially responsible and conscious.
GC10. Skills in using information and communication technologies.
GC11. The ability to work in a team.
GC13. The ability to preserve and multiply moral, cultural, scientific values and achievements of society based on understanding the history and patterns of development of the subject area, its place in the general system of knowledge about nature and society and in the development of society, technology and technology, to use various types and forms of physical activity for active recreation and leading a healthy lifestyle.
Professional (special) competencies (PC):
PC1. The ability to apply typical analytical methods and computer software to solve engineering problems in the field of mechanical engineering, effective quantitative methods of mathematics, physics, engineering sciences, as well as appropriate computer software to solve engineering problems in the field of mechanical engineering.
PC2. The ability to apply fundamental scientific facts, concepts, theories, principles to solve professional problems and practical problems in the field of mechanical engineering.
PC3. The ability to evaluate and ensure the quality of work performed.
PC4. The ability to implement engineering developments in industrial mechanical engineering, taking into account technical, organizational, legal, economic and environmental aspects throughout the entire life cycle of the machine: from design, construction, operation, maintenance of operability, diagnostics and disposal.
FC5. The ability to use computerized design systems and specialized application software to solve engineering problems in the field of mechanical engineering.
FC6. The ability to assess the technical and economic efficiency of typical systems and their components based on the application of analytical methods, analysis of analogues and the use of available data.
FC7. The ability to make effective decisions regarding the choice of structural materials, equipment, processes and to combine theory and practice to solve an engineering problem.
FC8. The ability to realize creative and innovative potential in project developments in the field of industrial mechanical engineering.
FC9. The ability to carry out commercial and economic activities in the field of industrial mechanical engineering.
Program Learning Outcomes (PLN):
PLN 1. Knowledge and understanding of the principles of technological, fundamental and engineering sciences that underlie the branch of mechanical engineering of the relevant industry.
PLN 2. Knowledge and understanding of mechanics and mechanical engineering and the prospects for their development.
PLN 3. Know and understand the systems of automatic control of objects and processes of mechanical engineering, have the skills to use them practically.
PLN 4. Perform engineering calculations to solve complex tasks and practical problems in mechanical engineering.
PLN 5. Analyze engineering objects, processes and methods.
PLN 7. Prepare for production and operate products using automatic life cycle support systems.
PLN 10. Understand the problems of occupational safety and legal aspects of engineering activities in mechanical engineering, skills to predict the social and environmental consequences of the implementation of technical tasks.
PLN 11. Communicate freely with the engineering community orally and in writing in the state and foreign languages.
PLN 12. Apply technical control tools to evaluate the parameters of objects and processes in industrial mechanical engineering.

PLN 13. Understand the structures and services of industrial mechanical engineering enterprises.
PLN 14. Develop machine parts and assemblies using computer-aided design systems.

2. The program and structure of discipline for

Title of thematic modules and Topics	Hour numbers												
			денна форма					Distance learning					
	Weeks	Total						Total	Including				
			l	p	lab	ind	i.s.		l	p	lab	ind	i.s.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Module 1. Geometry and kinematics of manipulation systems													
Topic 1. Structural analysis of agricultural robots. Features of the kinematics of manipulators for working with biological objects.	1-2	18	4		4		10						
Topic 2. Matrix methods for describing the spatial position of links. Matrices of homogeneous transformations.	3-4	18	4		4		10						
Topic 3. Direct kinematics problem. Denavit-Hartenberg method for field and garden robots.	5-6	18	4		4		10						
Topic 4. Inverse kinematics problem. Features of analytical solutions for 3D/4D manipulators.	7-8	18	4		4		10						
Total of module 1	72		16		16		40						
Module 2. Structural design of links, hinges and guides													
Topic 1. Designs of manipulator links. Open and closed cross-section profiles. Welded, cast and stamped links of agricultural manipulators.	9-10	18	4		4		10						
Topic 2. Movable joints and hinge assemblies. Designs of rotary axes, bearing support assemblies of robots.	11-12	18	4		4		10						
Topic 3. Linear	13-14	18	4		4		10						

Motion Guides													
Topic 4. Structural elements of balancing mechanisms	15	14	2		2		10						
Total of module 2	68		14		14		40						
Total hour of Semester 7	140		30		30		80						
Module 3. Power systems and actuators of agricultural robots.													
Topic 1. Selection of drives. Features of hydraulic and pneumatic drives for severe operating conditions	1-2	18	4		4		10						
Topic 2. Mechanical transmissions. Calculation of closed gearboxes and moving parts protection systems.	3-4	18	4		4		10						
Topic 3. Stiffness of elements of long-range manipulators	5-6	18	4		4		10						
Topic 4. Calculation of specialized clamps (vacuum, elastic, adaptive) for delicate bioobjects.	7-8	18	4		4		10						
Total of module 3	72		16		16		40						
Module 4. Durability and reliability in the agro-industrial complex													
Topic 1. Positioning accuracy taking into account vibrations of the tractor chassis or mobile platform.	9-10	18	4		4		10						
Topic 2. Static and dynamic calculation of links for strength. Influence of vibrations from internal combustion engines and soil.	11-12	18	4		4		10						
Topic 3. Reliability and dust and moisture protection (IP65/IP67 standards) of robot elements.	13	22	2		2		18						
Total of module 4	58		10		10		38						
Total hour of Semester 8	130		26		26		78						
Course project (work)			-	-		30	-						
Total hours	300		56		56	30	158						

3. Topics of Lectures

№	Topic title	Hour numbers
1	Structural analysis of agricultural robots. Features of the kinematics of manipulators for working with biological objects.	4
2	Matrix methods for describing the spatial position of links. Matrices of homogeneous transformations.	4
3	Direct kinematics problem. Denavit-Hartenberg method for field and garden robots.	4
4	Inverse kinematics problem. Features of analytical solutions for 3D/4D manipulators.	2
5	Designs of manipulator links. Open and closed cross-section profiles. Welded, cast and stamped links of agricultural manipulators.	4
6	Movable joints and hinge assemblies. Designs of rotary axes, bearing support assemblies of robots.	4
7	Linear Motion Guides	4
8	Structural elements of balancing mechanisms	4
9	Selection of drives. Features of hydraulic and pneumatic drives for severe operating conditions	4
10	Mechanical transmissions. Calculation of closed gearboxes and moving parts protection systems.	4
11	Stiffness of elements of long-range manipulators	4
12	Calculation of specialized clamps (vacuum, elastic, adaptive) for delicate bioobjects..	4
13	Positioning accuracy taking into account vibrations of the tractor chassis or mobile platform	4
14	Static and dynamic calculation of links for strength. Influence of vibrations from internal combustion engines and soil..	4
15	Reliability and dust and moisture protection (IP65/IP67 standards) of robot elements.	2
	Total	26

4. Topics of laboratory classes

№	Topic title	Hour numbers
1	Research on the structure and construction of the manipulator working area	4
2	Compiling Denavit-Hartenberg matrices for an anthropomorphic robot	4
3	Kinematic analysis of the robot mechanism	4
4	Solving the direct kinematics problem for a three-link manipulator	2
5	Modeling a rigid spatial link of a box section	4
6	Design and selection of a bearing assembly for the rotary joint of an agricultural manipulator	4
7	Modeling and kinematic analysis of the telescopic extension mechanism of the manipulator link	4
8	Design development and integration of a spring weight compensator for the vertical link of the robot	4
9	Calculation and selection of hydraulic drive	4
10	Modeling and calculation of the geometry of an adaptive harvester for harvesting vegetables	4
11	Determination of deformations of the long boom of the manipulator under load	4

12	Force calculation of the mechanism for clamping stems/fruits without their destruction	4
13	Calculation of the manipulator link for strength and safety factor	4
14	Frequency analysis of the design to prevent resonance	4
15	Assessment of the accuracy of the manipulator operation in the presence of play in worn hinges	2
	Total	56

5. Topics for self-study

№	Topic title	Hour numbers
1	General information about robots and manipulators.	40
2	Mechanical system and drive mechanisms of industrial robots and manipulators	40
3	Transmission mechanisms of industrial robots	39
4	Movement mechanisms of industrial robots	39
	Total	158

6. Tools for assessing expected learning outcomes:

- exam;
- module tests;
- laboratory work defense.

7. Teaching methods^

– – problem-based learning method;
– – practice-oriented learning method;
– – project-based learning method;
– – flipped classroom method, blended learning;
– – research-based learning method;
– – educational discussions and debates method;
– – teamwork, brainstorming method
– – verbal method (lecture, interview, etc.);
– – practical method (laboratory, practical classes);
– – visual method (illustration method, demonstration method);
– – work with educational and methodological literature (note-taking, theses, annotation, review, writing an abstract);
– – video method (distance, multimedia, web-based, etc.);
– – independent work (task completion);
– – individual research work of higher education students.

8. Results assessment.

The student's knowledge is assessed by means of a 100-point scale converted into the national grades according to the "Exam and Credit Regulations at NULES of Ukraine" in force

8.1. Distribution of points by types of educational activities

Educational activity	Results	Assessment
7 semester		
Module 1. Geometry and kinematics of manipulation systems		
Laboratory work 1.	PLN 1, PLN 2, PLN 3, PLN 4, PLN 5, PLN 7, PLN 10, PLN 11, PLN 12, PLN 13, PLN 14. The student must know:	**14**
Laboratory work2		**14**
Laboratory work3.		**14**
Laboratory work4.		**14**

Independent work 1.	the basics of designing elements of robots, manipulators and their drives. He must be able to design and calculate the working area of a robot and a manipulator based on the analysis of existing elements and structures. Know the composition of regulatory and technical documentation for designing elements of robots and manipulators with optimal parameters in terms of efficiency, durability, repairability, etc. in accordance with the requirements of the ESKD. Be able to determine materials for manufacturing structural elements of robots and manipulators depending on the functional purpose.	**14**
Module wor 1.		**30**
Total for module 1		**100**
Module 2. Structural design of links, hinges and guides		
Laboratory work 5.	PLN 1, PLN 2, PLN 3, PLN 4, PLN 5, PLN 7, PLN 10, PLN 11, PLN 12, PLN 13, PLN 14. Be able to design elements of a mechanical system, orienting mechanisms. Be able to design elements of a supporting system. Be able to design elements of a hydraulic drive executive system, be able to design elements of a pneumatic drive executive system, be able to design elements of an electric drive executive system. Be able to develop the design of handle mechanisms. Be able to calculate transmission shafts.	**14**
Laboratory work 6.		**14**
Laboratory work 7.		**14**
Laboratory work 8.		**14**
Independent work 2.		**14**
Module wor 2.		**30**
Total for module 2		**100**
Class work		**(M1 + M2)/2*0,7 ≤ 70**
Credit		**30**
Total for 7 semester		**(Class work + credit) ≤ 100**
8 semester		
Module 3. Power systems and actuators of agricultural robots..		
Laboratory work 1.	PLN 1, PLN 2, PLN 3, PLN 4, PLN 5, PLN 7, PLN 10, PLN 11, PLN 12, PLN 13, PLN 14. Be able to know the design and be able to calculate couplings. Be able to calculate the transmission mechanisms of the handle. Be able to determine the types of gripping devices and carry out their design calculation. Be able to calculate and design the mechanisms for connecting the links. Be able to know the design and calculate	**14**
Laboratory work 2.		**14**
Laboratory work 3.		**14**
Laboratory work 4.		**14**
Independent work 1.		**14**
Module wor 3.		**30**

	the rotation mechanisms. Be able to determine the forces on the output links of the rotation mechanisms for various kinematic layouts of robots and manipulators. Be able to calculate the worm, planetary and wave transmission.	
Total for module 3		**100**
Module 4. Durability and reliability in the agro-industrial complex		
Laboratory work 5	PLN 1, PLN 2, PLN 3, PLN 4, PLN 5, PLN 7, PLN 10, PLN 11, PLN 12, PLN 13, PLN 14. Be able to know the design and be able to calculate the support units of rotation mechanisms. Be able to know the design and be able to calculate the elements of linear sliding displacement. Be able to know the design and be able to calculate the elements of linear rolling displacement. Be able to calculate the transmission mechanisms of linear displacement	**17**
Laboratory work 6		**17**
Laboratory work 7		**17**
Independent work 2.		**19**
Module wor 4.		**30**
Total for module 4		**100**
Class work		**(M1 + M2)/2*0,7 ≤ 70**
Exam		**30**
Total for 8 semester		**(Class work + credit) ≤ 100**
Course project (work)		**100**

8.2. Scale for assessing student's knowledge

Student's rating, points	National grading (exam/credits)
90-100	excellent
74-89	good
60-73	satisfactory
0-59	unsatisfactory

8.3. Assessment policy

Deadlines and exam retaking rules	EXAMPLE: works that are submitted late without valid reasons will be assessed with a lower grade. Module tests may be retaken with the permission of the lecturer if there are valid reasons (e.g. a sick leave).
Academic integrity rules	EXAMPLE: cheating during tests and exams is prohibited (including using mobile devices). Term papers and essays must have correct references to the literature used
Attendance rules	EXAMPLE: Attendance is compulsory. For good reasons (e.g. illness, international internship), training can take place individually (online by the faculty dean's consent)

9. **Teaching and learning aids:**

e-learning course of the discipline

https://elearn.nubip.edu.ua/course/view.php?id=5683

https://elearn.nubip.edu.ua/course/view.php?id=5684

10. Recommended sources of information

1. Mikhailov E. P. Manipulators and industrial robots [Text]: textbook / Mikhailov E. P., Lingur V. M. — Odesa: ONPU, 2019, -233 p.

2. Koshel S. O. Design of industrial robots and manipulators: manual / S. O. Koshel, Yu. Kovalev, O. P. Manoilenko — Kyiv: Center for Educational Literature, 2019. — 256 p.

3. Current standards of the ESKD.

4. Mishchuk D. O. Design and construction of robotic systems: Textbook – Kyiv: 2020. – 185 p.

5. Mishchuk D. O. Robots and manipulators: manual – Kyiv: 2020. – 268 p.

6. Nevlyudov I. Sh., Andrusevich A. O., Yevseev V. V., Novoselov S. P., Demska N. P. Design of mobile manipulation robots: Monograph / I. Sh. Nevlyudov, A. O. Andrusevich, V. V. Yevseev, S. P. Novoselov, N. P. Demska– Kh.: 2022. – 427 p.

7. Eugene Kagan, Nir Shvalb, Irad Ben-Gal. Autonomous Mobile Robots and Multi-Robot Systems. John&Son Ltd. 2020. P. 319.

8. Robotique agricole: repenser la mécanisation agricole. [Type of medium]. Available: https://www.entraid.com/articles/robotique-agricole-opportunite-repenser-mecanisation agricole

9. Robot Più Strani Ed Utili Mai Costruiti. [Type of medium]. Available: https://www.smartweek.it/10-robot-piu-strani-ed-utili-mai-costruiti/6/

10. Boston Dynamics. [Type of medium]. Available: https://www.bostondynamics.com/

11. KUKA Roboter robots: https://www.kuka.com

12. FANUC robots.URL: http://www.fanucrobotics.com/Products/Robots/Atoz.aspx

13. Kawasaki robots: http://www.kawasakirobotics.com/products/?page=robots

14. ABB robots: http://www.abb.ru/product/us/9AAC100735.aspx

15. MOTOMAN welding robots: http://www.motoman.com/products/robots/arc-welding-robots.php