National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

Department
biomedical engineering

Mechanics and Biomechanics

Working program of basic discipline (Silabus)

Requisites for basic discipline	
Level of higher education	***First (bachelor's)***
Branch of knowledge	*16 Chemical and Bioengineering*
Specialty	*163 Biomedical Engineering*
Educational program	*Medical Engineering*
Discipline status	*Mandatory discipline*
Form of study	*full-time / day / mixed / remote*
Year of preparation, semester	*2th course, spring semester*
The scope of discipline	*6 ECTS credits / 180 hours*
Semester control / Control measures	*Exam, Modular Test Work, Calculation and Graphic Work*
Lessons schedule	*According to the schedule on the site http://rozklad.kpi.ua/*
Language of instruction	*English*
Information about course leader / teachers	***Lecturer:*** *PhD in Pedagogy, Associate Professor, Associate Professor of the Department of BME, Tetyana Bohdanova, e-mail: t.bogdanova@lll.kpi.ua* ***Practical classes:*** *PhD in Pedagogy, Associate Professor, Associate Professor of the Department of BME, Tetyana Bohdanova, e-mail: t.bogdanova@lll.kpi.ua*
Course placement	*Platform «Sikorsky»*

Distribution of hours

Semester	Lectures	Practical	Laboratory	Independent Work
autumn semester	*36*	*54*		*90*

Curriculum of the discipline

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

The course "Mechanics and Biomechanics" is a fundamental component of the professional training of bachelors in the specialty 163 "Biomedical Engineering" and is aimed at developing the engineering mindset necessary for analyzing and modeling mechanical processes in technical and biological systems.

The main objective of the course is to equip students with the ability to solve complex specialized tasks and practical problems in biomedical engineering, which involves applying the laws and methods of classical mechanics, strength of materials, and biomechanics to analyze motion, equilibrium, and deformation of technical objects and biological tissues.

The course "Mechanics and Biomechanics" covers the basic concepts and laws of theoretical mechanics (kinematics, dynamics, statics), principles of interaction and motion of material bodies, conditions of equilibrium of mechanical systems, as well as the fundamentals of strength of materials. Special attention is given to the application of these principles to biological objects: analyzing forces acting on tissues, organs, and human body systems, studying the mechanics of the musculoskeletal system, biomechanics of bone levers, and the mechanical and rheological behavior of biological tissues.

During the course, students acquire the skills to perform biomechanical analysis of human movement, develop mathematical and rheological models of the mechanical behavior of biological

tissues, interpret biomechanical characteristics of human organs and systems, and apply the acquired knowledge in the design, research, and operation of biomedical devices and systems.

Prerequisites for the course include:

1. *Basic knowledge of higher mathematics (vectors, derivatives, integrals, differential equations);*
2. *Fundamentals of physics (mechanics, oscillations, elements of molecular physics);*
3. *Skills in working with graphs, formulas, and physical quantities;*
4. *Basic computer skills and the use of numerical computation methods;*
5. *Ability to analyze physical processes and construct simplified mathematical models;*
6. *Elementary skills in working with engineering and educational software tools.*

***General competencies** (OPP was put into effect by the Rector's Order NON/434/2024 of 10.06.2024 p.):*

***ZK 06 -** Ability to search, process, and analyze information from various sources*

***Special (professional) competencies** (OPP was put into effect by the Rector's Order NON/434/2024 of 10.06.2024 p.):*

***FK 04** - Ability to ensure the technical and functional characteristics of systems and tools used in medicine and biology (for prevention, diagnosis, treatment, and rehabilitation).*
***FK 06** - Ability to effectively use tools and methods for analysis, design, calculation, and testing in the development of biomedical products and services*

***The program learning outcomes after studying the discipline "Mechanics and Biomechanics" are** (OPP was put into effect by the Rector's Order NON/434/2024 of 10.06.2024 p.):*

***PRN 01 -** The ability to apply knowledge of the fundamentals of mathematics, physics and biophysics, bioengineering, chemistry, engineering graphics, mechanics, materials resistance and strength, properties of gases and liquids, electronics, computer science, signal and image acquisition and analysis, automatic control, system analysis, and decision-making methods at a level necessary for solving biomedical engineering tasks.*
***PRN 08** - Understand theoretical and practical approaches to the creation and management of medical equipment and medical technology.*
***PRN 19** - Proficiency in engineering methods for calculating components of medical devices and systems, modern methods for experimental verification of integrity and functionality of biotechnical systems and determination of their characteristics, methods for selecting conventional and advanced construction materials, as well as tools for designing devices, instruments, and systems for medical and biological purposes.*

2. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)

The course "Mechanics and Biomechanics" belongs to the cycle of professional training and has an interdisciplinary character, combining the fundamental laws of classical mechanics with applied approaches to the analysis of mechanical processes in biological systems. The course provides the theoretical and methodological foundation for the further mastery of engineering and biomedical educational components.

According to the structural-logical scheme of the educational program, the course "Mechanics and Biomechanics" builds upon knowledge acquired during the study of general and fundamental training courses, in particular: Higher Mathematics*;* Physics*;* Biophysics*;* Biochemistry*;* Human Anatomy and Physiology*. These courses provide the necessary mathematical, physical, and scientific basis for*

understanding the laws of mechanics, analyzing motion, equilibrium, and deformation of bodies, as well as the mechanical behavior of biological tissues.

The theoretical knowledge and practical skills obtained during the study of "Mechanics and Biomechanics" are applied in further learning of courses from the professional training cycle (Educational and Professional Program Medical Engineering*):* Biomedical Devices, Apparatus, and Complexes*;* Materials Science and Structural Materials*;* Mechanics of Biomaterials and Biocompatibility*;* Microprocessor Technology*;* Biomedical Signal Processing*; as well as in elective courses (Educational and Professional Program* Medical Engineering*): courses related to the design, analysis, and operation of medical and rehabilitation devices, orthopedic and prosthetic systems, and the biomechanical analysis of human movement.*

Thus, the course "Mechanics and Biomechanics" occupies a key position in the structure of professional training for bioengineers, ensuring continuity between fundamental natural science courses and specialized engineering and biomedical educational components.

3. The content of the discipline

The main sections and topics that will be considered in the process of studying the course:

Section 1. Fundamentals of Statics and Solid Mechanics

Subject 1.1. Application of basic laws of mechanics for the analysis of forces and equilibrium conditions
Subject 1.2. Calculation of force moments and resultant forces in mechanical systems
Subject 1.3. Analysis of equilibrium of bodies under arbitrary forces and friction forces

Section 2. Kinematics and Dynamics of Mechanical and Biomechanical Systems

Subject 2.1. Determination of kinematic characteristics of motion in mechanical and biomechanical systems
Subject 2.2. Solving dynamic problems in mechanics using energy methods

Section 3. Strength of Materials and Mechanics of Biological Materials

Subject 3.1. Calculation of stress-strain state of structural elements and biological tissues
Subject 3.2. Modeling the mechanical and rheological behavior of biological materials

Section 4. Fundamentals of Biomechanics of Movement and Functional Systems

Subject 4.1. Biomechanical analysis of human movement and the musculoskeletal system
Subject 4.2. Application of biomechanical models in biomedical systems and devices

Section 5. Summary and Assessment

Subject 5.1. Evaluation of the development of engineering competencies in mechanics and biomechanics

4. Training materials and resources

Basic literature:

1. *Механіка. Конспект лекцій [Електронний ресурс] : навчально-методична праця для здобувачів ступеня бакалавра за спеціальністю 163 Біомедична інженерія / КПІ ім. Ігоря Сікорського ; уклад.: Л. Д. Тарасова. – Електронні текстові дані (1 файл: 3,54 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2021. – 228 с. - Назва з екрана. https://ela.kpi.ua/handle/123456789/68537*

2. *Механіка. Практикум [Електронний ресурс] : навчальний посібник для здобувачів ступеня бакалавра за спеціальністю 163 Біомедична інженерія / КПІ ім. Ігоря Сікорського ; уклад.: Л. Д. Тарасова. – Електронні текстові дані (1 файл: 4,47 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2024. – 212 с. – Назва з екрана. https://ela.kpi.ua/handle/123456789/67831*
3. *Механіка. Розрахунково-графічна робота [Електронний ресурс] : навчальний посібник для здобувачів ступеня бакалавра за освітньою програмою «Медична інженерія» спеціальності 163 «Біомедична інженерія» / КПІ ім. Ігоря Сікорського ; уклад. Л. Д. Тарасова. – Електронні текстові дані (1 файл: 1,28 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2022. – 60 с. – Назва з екрана. https://ela.kpi.ua/handle/123456789/48263*
4. *Лебедєва І.В., Борисейко О.В., Курилко О.Б. Кінематика. Приклади і задачі: Навчальний посібник. – Електронне видання. – 2019. – 151 с. Посилання на ресурс: https://www.mechmat.univ.kiev.ua/wp-content/uploads/2021/01/kinematyka.pryklady_-i_zadachi.pdf*
5. *Шваб'юк В.І. Опір матеріалів: Підручник. – К.: Знання, 2016. – 400 с. https://btpm.nmu.org.ua/ua/download/navch-posib/%D0%A8%D0%B2%D0%B0%D0%B1%D1%8E%D0%BA.%D0%9E%D0%9C.%D0%9F%D1%96%D0%B4%D1%80%D1%83%D1%87%D0%BD%D0%B8%D0%BA.pdf*
6. *Тарасова, Л.Д. Біомедична механіка. Збірник завдань до домашніх контрольних робіт [Електронний ресурс]: навч. посіб. для здобувачів ступеня бакалавра за освітньою програмою «Медична інженерія» спеціальності 163 «Біомедична інженерія» / Л.Д. Тарасова; КПІ ім. Ігоря Сікорського. – Електронні текстові дані (1 файл: 1,36 Мбайт). – Київ: КПІ ім. Ігоря Сікорського, 2020. – 45 с. – Доступ:* https://ela.kpi.ua/handle/123456789/34678.
7. *Біомеханіка. Конспект лекцій для здобувачів ступеня бакалавра спеціальності 132 Матеріалознавство / С.П. Панченко; Нац. техн. ун-т «Дніпровська політехніка». – Д. : НТУ «ДП», 2022. – 73 с.*

Additional literature:

8. *Березін Л.М. Теоретична механіка. Частина 1. Статика, кінематика: навч. посіб. /Л.М.Березін та ін. – К.: Університет "Україна", 2021. – 142 с.*
9. *Дейниченко Г.В., Цвіркун Л.О., Омельченко О.В. Теоретична механіка : навч. посіб. Кривий Ріг: ДонНУЕТ, 2021. 107 с.*
10. *Лебедєва І.В., Борисейко О.В., Курилко О.Б. Динаміка матеріальної системи. Методичні вказівки до проведення практичних занять. – Електронне видання. – 2021. – 100 с.*
11. *Теоретична механіка: Конспект лекцій [Електронний ресурс] : навч. посіб. для студ. спеціальності: 151 "Автоматизація та комп'ютерно – інтегровані технології", спеціалізацій "Автоматизація хіміко – технологічних процесів і виробництв", "Комп'ютерно – інтегровані технології хімічних та нафтопереробних виробництв" / КПІ ім. Ігоря Сікорського ; уклад.: Н.І. Штефан, Н.В. Гнатейко, В.М. Федоров. – Електронні текстові дані (1 файл: 6,98 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2019. – 143 с. https://ela.kpi.ua/server/api/core/bitstreams/8abf76d7-bb08-4f69-8028-ec484dd8b5ed/content*
12. *Knudson, D. (2021).* Fundamentals of biomechanics *(5th ed.). Springer. https://doi.org/10.1007/978-3-030-61601-6*
13. *Конспект лекцій з дисципліни «Біомедична механіка» для здобувачів освітнього рівня «бакалавр» спеціальності 163 – Біомедична інженерія, освітня програма «Біомедична інженерія» / уклад. Д. Х. Штофель. Вінниця : ВНТУ, 2020. 83 с.*
14. *Craelius, W. (2021).* Prosthetic Designs for Restoring Human Limb Function. *Cham: Springer. 224 с. [Електронний ресурс]. DOI: https://doi.org/10.1007/978-3-030-31077-6*
15. *Arazpour, M. (ed.) (2021).* Prosthetics and Orthotics. *London: IntechOpen. 144 с.*

Educational content

5. Methods of mastering the discipline (educational component)

№ s/n	Subject	Program learning outcomes	The main tasks	
			Control measure	Deadline
1.	Application of basic laws of mechanics for the analysis of forces and equilibrium conditions	PRN 01	Practical work 1	Week 1
2.	Calculation of force moments and resultant forces in mechanical systems	PRN 01	Practical work 2-3	Weeks 2–3
3.	Analysis of equilibrium of bodies under arbitrary forces and friction forces	PRN 01	Practical work 4-6	Weeks 4–5
4.	Determination of kinematic characteristics of motion in mechanical and biomechanical systems	PRN 01	Practical work 7-9	Weeks 6–7
5.	Solving dynamic problems in mechanics using energy methods	PRN 01, PRN 19	Practical work 10-12	Weeks 8–9
6.	Calculation of stress-strain state of structural elements and biological tissues	PRN 01, PRN 19	Practical work 13-15	Weeks 10–11
7.	Modeling the mechanical and rheological behavior of biological materials	PRN 01, PRN 19 2	Practical work 16-18	Weeks 12–14
8.	Biomechanical analysis of human movement and the musculoskeletal system	PRN 08	Laboratory work 19-22	
9.	Application of biomechanical models in biomedical systems and devices	PRN 08, PRN 19	Practical work 23-26	Week 15
10.	Evaluation of the development of engineering competencies in mechanics and biomechanics	PRN 01	Modular Test Work	Week 15

Lectures

Lecture topics:

1. ***Application of Basic Concepts and Laws of Mechanics in Biomedical Engineering***

Subject and objectives of mechanics and biomechanics. Mechanics as a foundation of engineering training for bioengineers. Objects of study in mechanics: material point, absolutely rigid body, mechanical system. Relationship between mechanics and biomedical engineering. Basic physical quantities and systems of units. The role of mechanics and biomechanics in the structure of professional training.

2. ***Analysis of Forces and Equilibrium Conditions of Mechanical and Biomechanical Systems***

Concept of force as a measure of mechanical interaction. Classification of forces. Projections of a force onto an axis and a plane. Analytical representation of forces. Axioms of statics. Constraints and their reactions. Equilibrium conditions of rigid bodies and biomechanical objects.

3. ***Calculation of Force Moments and Resultants of Force Systems***

Moment of a force with respect to a point and an axis. Moment vector of a force. Varignon's theorem. Concept of a force couple and moment of a couple. Resultant of a force system. Center of gravity of a rigid body. Biomechanical examples of force moments (levers of the musculoskeletal system).

4. ***Analysis of Equilibrium of Bodies under Arbitrary Forces and Friction Forces***

Arbitrary force systems. Principal vector and principal moment. Equilibrium conditions of planar

and spatial force systems. Dry friction forces. Coulomb's law. Angle and cone of friction. Biomechanical aspects of friction in joints and body–support contact.

5. ***Determination of Kinematic Characteristics of Motion***

Fundamental problem of kinematics. Kinematics of a material point. Translational and rotational motion of a rigid body. Angular velocity and angular acceleration. Formulas for determining velocities and accelerations of body points. Kinematic pairs. Kinematics of movement in biomechanics.

6. ***Analysis of Planar, Complex, and Spherical Motion of a Rigid Body***

Planar motion of a rigid body. Instantaneous center of velocities. Determination of velocities and accelerations of points of a planar figure. Complex motion. Theorems of velocity and acceleration addition. Coriolis acceleration. Spherical motion of a body. Biomechanical examples of body segment motion.

7. ***Application of Fundamental Laws of Dynamics to Mechanical and Biomechanical Systems***

Axioms of dynamics. First and second problems of dynamics. Momentum of a material point and a system. Impulse of force. Theorem of momentum change. Motion of the center of mass of a mechanical system. Examples of dynamics of movements in biomechanics.

8. ***Use of Energy Methods in Mechanics***

Kinetic energy of a material point, rigid body, and mechanical system. König's theorem. Work of a force and a moment of force. Theorem of kinetic energy change. Work of friction forces. Energy-based approaches to the analysis of biomechanical processes.

9. ***Calculation of Stresses and Deformations of Structural Elements***

Fundamentals of strength of materials. Basic hypotheses and assumptions. Stress and strain. Hooke's law. Strength and stiffness characteristics of materials. Allowable stresses. Biomedical examples of loading of structural elements and implants.

10. ***Analysis of Stress–Strain State under Shear, Torsion, and Bending***

Shear and torsion. Distribution of shear stresses. Strength and stiffness calculations. Bending of rods. Transverse forces and bending moments. Diagrams of internal force factors. Strength conditions under bending. Biomechanical analogs of bone loading.

11. ***Mechanical and Rheological Properties of Biological Materials***

Features of mechanical behavior of biological tissues. Elastic, viscous, and viscoelastic properties. Rheological models (Hooke, Maxwell, Kelvin–Voigt). Mechanical properties of bone, cartilage, and tendons. Importance of rheology for biomedical engineering.

12. ***Biomechanics of the Human Musculoskeletal System***

Biomechanical structure of the musculoskeletal system. Muscles as active force-generating elements. Tendons and ligaments. Transmission and transformation of mechanical forces in biomechanical systems.

13. ***Statics and Quasi-Statics of Multisegment Biomechanical Models***

Biomechanical levers. Equilibrium of body segments. Determination of joint reaction forces. Muscle loading during static and slow movements.

14. ***Kinematics and Dynamics of Human Movement***

Biokinematic chains and pairs. Degrees of freedom of joints. Dynamic models of movement. Calculation of forces and moments during motion of body segments.

15. ***Biomechanics of Human Locomotion***

Walking, running, jumping. Phases of movement. Ground reaction forces. Energy expenditure during locomotion. Pendulum models of movement.

16. ***Biomechanics of Biological Fluids***

Fundamentals of fluid mechanics in biological systems. Laminar and turbulent flow regimes. Non-Newtonian properties of biological fluids. Biomechanical features of blood flow and other fluids in the human body.

17. ***Biomechanics of the Cardiovascular and Respiratory Systems***

Hemodynamics of blood circulation. Pulse waves. Mechanics of respiration. Airway resistance. Work of respiratory muscles.

18. ***Engineering Biomechanical Models in Biomedical Engineering***

Mechanical and mathematical modeling of biological systems. Biomechanics of implants and prostheses. Application of biomechanical models in diagnostics, treatment, and rehabilitation.

Practical works

The main objectives of the practical sessions in the course "Mechanics and Biomechanics" are to consolidate and deepen the fundamental principles of mechanics and biomechanics through the solution of applied engineering problems, performance of calculations, and analysis of biomechanical models used in the design, research, and operation of biomedical systems and devices.

The practical sessions aim to develop students' ability to apply the laws of classical mechanics, analyze the mechanical properties of biological materials, model motion and deformation of elements of biological systems, and interpret the obtained results from a biomechanical perspective. The tasks of the practical sessions are oriented toward typical engineering situations encountered in the professional activities of a biomedical engineer and in the completion of coursework and master's projects.

Each practical session includes assessment of students' understanding of theoretical material, solving computational and analytical problems, discussion of results, completion of individual or group assignments, as well as verification and evaluation of students' work outcomes.

Grades obtained in individual practical sessions are recorded in the academic group's grade register and are taken into account when determining the final cumulative grade for the course "Mechanics and Biomechanics."

No.	Practical work topic	Number of Hours
Section 1. Fundamentals of Statics and Solid Mechanics		
1	Force and its projections onto axes and planes	2
2	Algebraic and vector moments of forces	2
	Calculation of the resultant of a system of concurrent forces	2
3	System of parallel forces. Center of gravity	2
4	Arbitrary force system. Equilibrium conditions	2
5	Equilibrium of bodies in the presence of friction forces	2
6	Force and its projections onto axes and planes	2
Section 2. Kinematics and Dynamics of Mechanical and Biomechanical Systems		
7	Kinematics of a material point	2
8	Kinematics of a rigid body and mechanical transmissions	2
9	Planar motion of a rigid body and mechanisms	2
10	Complex and spherical motion of a rigid body	2
11	Center of mass of a mechanical system	2
12	Theorems of dynamics. Work and energy	2
Section 3. Strength of Materials and Mechanics of Biological Materials		
13	Method of sections. Determination of internal force factors	2
14	Construction of shear force and bending moment diagrams	2
15	Stress calculation under tension and compression	2
16	Shear and torsion. Strength and stiffness calculations	2
17	Elastic properties of materials. Hooke's law	2
18	Rheological models of biological tissues (Maxwell, Kelvin–Voigt)	2
Section 4. Fundamentals of Biomechanics of Movement and Functional Systems		
19	Determination of the human body center of mass and equilibrium conditions	2

20	*Analysis of joint movements (axes, range of motion, degrees of freedom)*	*2*
21	*Analysis of movement dynamics (running, jumping, lifting a load)*	*2*
22	*Biomechanical analysis of the gait cycle*	*2*
23	*Modeling of biomechanical systems: levers and muscle forces*	*2*
24	*Modeling of biomechanical systems: kinematic chains*	*2*
Section 5. Summary and Assessment		
25	*Fluid mechanics in biomedical systems (laminar flow)*	*2*
26	*Modeling of blood flow and biohydraulic systems*	*2*
27	*Modular assessment test*	*2*
Total		*54*

6. Independent student work

Independent study includes preparation for lectures and practical classes, completion of assignments related to practical class topics, preparation for the modular assessment test, completion of the calculation-and-graphical assignment, and preparation for the examination.

6.1. Preparation for Lectures and Practical Classes

For preparation for lectures and practical classes, the student is required to study the prescribed core and supplementary literature, recommended sources, and prepare materials for discussion during classes. A total of 18 hours of independent study is allocated for this activity.

6.2. Completion of Assignments Related to Practical Classes

A total of 42 hours of independent study is allocated for performing calculations and preparing reports for practical classes.

6.3. Preparation for the Modular Assessment Test

6 hours of independent study are allocated for preparation for the modular assessment test.

6.4. Calculation-and-Graphical Assignment (CGA)

A total of 14 hours of independent study is allocated for the preparation and completion of the calculation-and-graphical assignment (CGA).

The student must select the topic of the CGA and agree it with the instructor no later than the 4th week of the semester. The deadline for submission of the CGA to the instructor is no later than the 13th week. The defense of the CGA is scheduled during an additional (unscheduled) class between weeks 13 and 15.

The main objective of the CGA is to solve practical problems using theoretical material studied during lectures and through independent learning, as well as practical skills acquired during practical classes. The core of the CGA consists of calculations and graphical materials, including diagrams, charts, vector diagrams, histograms, etc. The student completes the CGA only on a topic approved by the instructor.

Approximate topics of the CGA:

- *Determination of support reactions of a composite structure.*
- *Absolutely rigid body under the action of an arbitrary spatial force system. Determination of support reactions.*
- *Planar motion of a rigid body. Kinematic analysis of a planar mechanism.*
- *Kinematic analysis of spherical motion of a rigid body rolling without slipping on a fixed surface.*
- *Study of the motion of a mechanical system using the theorem of motion of the center of*

mass.

- *Study of the motion of a mechanical system using the theorem of change of kinetic energy.*
- *Study of the motion of a mechanical system using the general equation of dynamics.*
- *Biomechanical analysis of human movement: calculation of joint forces during walking or lifting a load.*
- *Determination of loads on musculoskeletal structures during different types of physical exercises.*
- *Modeling of the mechanics of the musculoskeletal system for the analysis of range of motion and force moments.*

6.5. Preparation for the Examination

A total of 10 hours of independent study is allocated for preparation for the examination.

№ s/n	*Types of Independent Study*	*Number of Hours*
1	*Preparation for lectures and practical classes*	*18*
2	*Completion of assignments related to practical classes*	*22*
3	*Independent study of additional topics for self-directed learning*	*20*
4	*Preparation for the modular assessment test*	*6*
5	*Completion of the calculation and graphical assignment*	*14*
6	*Preparation for the examination*	*10*
Total		*90*

No.	***Titles of topics and issues assigned for independent study and references to learning resources***	***Number of hours (self-study)***
1	*Topic 1.1. Application of basic laws of mechanics for the analysis of forces and equilibrium conditions. List of issues: Idealization of mechanical and biomechanical objects. Typical calculation schemes. Analysis of equilibrium of simple mechanical and biomechanical systems.*	*4*
2	*Topic 2.1. Determination of kinematic characteristics of motion of mechanical and biomechanical systems. List of issues: Kinematics of a material point and a rigid body. Determination of velocities and accelerations. Kinematic description of human motion.*	*4*
3	*Topic 3.1. Calculation of the stress–strain state of structural elements and biological tissues. List of issues: Basic types of stresses and strains. Hooke's law. Comparison of mechanical properties of engineering materials and biological tissues.*	*4*
4	*Topic 4.1. Biomechanical analysis of human movements and the musculoskeletal system. List of issues: Biomechanical levers. The role of muscles in motion generation. Joint loading under static and quasi-static conditions.*	*4*
5	*Topic 4.2. Application of biomechanical models in biomedical systems and devices. List of issues: Fundamentals of biomechanical modeling. Examples of model application in prosthetics, orthotics, and rehabilitation. Generalization of the course material.*	*4*
Total		*20*

List of recommended literature for studying the topics and issues assigned for independent study

1. ***Писаренко Г. С., Квітка О. Л., Уманський Е. С.*** Опір матеріалів : підручник / *Г. С. Писаренко, О. Л. Квітка, Е. С. Уманський. – 2-ге вид., переробл. – К. : Вища школа, 2004. – 655 с.*

Режим доступу: https://chtyvo.org.ua/authors/Pysarenko_Hryhorii/Opir_materialiv/

2. ***Шкельов Л. Т., Станкевич А. М., Пошивач Д. В.*** Опір матеріалів : підручник для студентів вищих навчальних закладів */ Л. Т. Шкельов, А. М. Станкевич, Д. В. Пошивач. – К. : ЗАТ «Віпол», 2011. – 456 с. Режим доступу: https://lib.in.ua/150204-pidruchnyk-opir-materialiv/*
3. ***Антоненко І. І., Перга С. М.*** Технічна механіка : навчальний посібник */ І. І. Антоненко, С. М. Перга. – Вінниця : ВНТУ, 2015. – PDF. Режим доступу: https://elibrary.kdpu.edu.ua/handle/0564/518*
4. ***Moebs W., Ling S. J., Sanny J.*** University Physics, Volume 1 : Mechanics, Waves, and Thermodynamics */ OpenStax, Rice University. – OpenStax 2016. PDF: https://assets.openstax.org/oscms-prodcms/media/documents/University_Physics_Volume_1_-_WEB.pdf*
5. ***Julio Gea-Banacloche*** University Physics I : Classical Mechanics – *Open educational resource, 2019. PDF: https://oer.unair.ac.id/items/show/174*
6. ***Salma Alrasheed*** Principles of Mechanics: Fundamental University Physics – *Open Textbook Library. Онлайн/завантаження: https://open.umn.edu/opentextbooks/textbooks/1600*

Policy and control

7. Policy of academic discipline (educational component)

Attending classes

Attendance at lectures is optional. Attending practical classes is desirable, as they are used to write express tests / tests, as well as to defend practical work.

The grading system is focused on obtaining points for student activity, as well as performing tasks that are able to develop practical skills and abilities.

Control measures missed

Missed control measures (defense of practical work) must be practiced in the next classes, provided that the task is scheduled for the current lesson, or in consultations.

Omissions of writing a module test and express test are not fulfilled.

Calculation and graphic work, which is submitted for inspection in violation of the deadline is evaluated with a decrease in the number of weight points.

Incentive points

Encouragement points	
Criterion	*Weight points*
Active participation in oral questioning	*+1 point*
Writing theses, articles, participation in international, national, and/or other events or competitions related to the course topic	*+5 points*

Academic integrity

The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: https://kpi.ua/code.

Norms of ethical behavior

Normative principles of behavior of students and employees, defined in sections 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: https://kpi.ua/code.

Procedure for appealing the results of control measures

Students have the opportunity to raise any issue related to the control procedure and expect it to be addressed according to predefined procedures.

The student has the right to appeal the results of the control measure according to the approved provision on appeals in the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (approved by the order №NON/128/2021 from 20.05.2021) - https://osvita.kpi.ua/index.php/node/182

Inclusive education

The course "Mechanics and Biomechanics" can be taught to most students with special educational needs, except for those with severe visual impairments that prevent them from completing tasks using personal computers, laptops, and/or other technical devices.

Distance learning

Distance learning is conducted via the "Sikorsky" distance learning platform. Completion of practical assignments and the modular assessment test is carried out during the student's independent study in a remote mode, with the possibility of consulting the instructor via email, Google Meet, or social media.

Distance learning through additional online courses on specific topics is allowed subject to agreement with the students. If a small number of students wish to complete an online course on a particular topic, studying the material through such courses is permitted, but students must complete all assignments required by the course. A list of recommended courses is provided by the instructor after identifying students' interests (since the pool of available courses is updated almost monthly).

A student provides a document confirming the completion of the distance course (in the case of completing the full course) or submits completed practical assignments from the distance course. Upon successfully passing an oral interview with the instructor on the covered topics, the student may receive grades for the assessment activities corresponding to the studied material.

Learning a foreign language

Teaching in English is carried out only for foreign students.

At the request of students, it is allowed to study the material with the help of English-language online courses on topics that correspond to the topics of specific classes.

8. Monitor and evaluate the system of evaluation of learning outcomes (Rating System of Evaluation)

Ongoing Control (OC). *Ongoing control is carried out during class sessions and aims to check students' preparedness for lectures and practical classes, as well as their current progress in completing the course program. During practical classes, students complete and defend reports for practical assignments. The control also includes completion of the modular control work and the semester control in the form of an examination.*

Calendar Control (CC). *Calendar control is performed twice a semester to monitor the current state*

of compliance with the syllabus requirements. There are two possible outcomes of calendar control: certified (C) and not certified (NC). The result depends on the number of points earned at the time of the calendar control. The minimum number of points required for certification during the first and second calendar control is indicated in the course gradebook.

Criterion			1st CC	2st CC
Calendar control week			7th week	14th week
Conditions for a positive result in Calendar Control	Ongoing rating		≥ 10,8 points	≥ 23,4 points
	Completion of practical assignments	№№ 1-12	+	+
		№№ 13-26	-	+
	Modular Control Work (MCW)	Graded MCW	-	-
	Calculation and Graphical Assignment (CGA)	Graded report	-	-

Grading System (Ongoing Control):

No.	Control Activity	%	Weight	Quantity	Total
1	Completion and defense of practical assignments	39	1.5	26	39
2	Modular Control Work (MCW)	10	10	1	10
3	Calculation and Graphical Assignment (CGA)	11	11	1	11
4	Exam	40	40	1	40
Total		100			100

Semester Control (Final Assessment)

Semester certification of students

Mandatory condition for admission to the test		Criterion
1	Current rating	RD ≥ 40
2	Completion of Modular Control Work (MCW)	At least 60% of the maximum score
3	Defense of Calculation and Graphical Assignment (CGA)	At least 60% of the maximum score

The results are announced to each student separately in the presence or remotely (by email). Also recorded in the system "Electronic Campus".

Optional Conditions for Admission to the Exam:

- *Active participation in practical classes.*
- *Positive result in the first and second calendar assessments.*
- *Attendance of lectures.*

Table of translation of rating points to grades on a university scale:

Number points	Assessment on the university scale
100-95	Perfectly

94-85	*Very good*
84-75	*Good*
74-65	*Satisfactorily*
64-60	*Enough*
Less 60	*Unsatisfactorily*
Admission conditions are not met	*Not allowed*

The exam is held orally.

9. Additional information on the discipline (educational component)

The list of questions for preparing the Modular Control Work, as well as for exam preparation, is provided in Appendix 1.

Work program of the discipline (syllabus):

Compiled by *Associate Professor of the Department of Biomedical Engineering, PhD in Pedagogy, Associate Professor Tetyana Bohdanova.*

Approved by *the Department of Biomedical Engineering (protocol № 15 of June 24, 2025)*

Approved by *the Methodical Commission of the Faculty of Biomedical Engineering (protocol № 12 of June 30, 2025)*

Appendix 1
*For syllabus of the discipline **"Mechanics and Biomechanics"***

List of Questions for Preparation for the Modular Control Work (MCW) and Exam

Block 1. Fundamentals of Statics and Forces

- *Formulate the main axioms of statics. Name the primary types of constraints, their characteristics, and reactions.*
- *Concept of force and its properties. Rules for determining the resultant force. Differences between resultant, equivalent, and equilibrant forces.*
- *Resultant of two parallel forces in the same and opposite directions. Provide examples.*
- *Distributed load. Determination of the concentrated force and moment produced by a distributed load.*
- *Moment of a force with respect to a point and an axis. Properties of the moment. Sign of the moment and cases when it is zero.*
- *Force couple: definition, properties, conditions for equivalence of force couples.*
- *Theorems on combining and transferring force couples in a plane and parallel planes.*
- *Theorem of parallel transfer of force and Poinsot's theorem.*
- *Reduction of a system of forces to the simplest system and to an arbitrary center.*
- *Equilibrium conditions of arbitrary spatial and planar force systems. Three forms of planar system equilibrium conditions.*

Block 2. Convergent and Planar Force Systems

- *Convergent force system. Theorem on the resultant of convergent forces.*
- *Equilibrium conditions of a convergent system, including planar. Three-force theorem.*
- *Varignon's theorem and moment of the resultant of a convergent force system.*
- *Statics invariants. Dependence of the principal moment of an arbitrary force system relative to a new center of reduction.*
- *Methodology for solving statics problems. Statically determinate and indeterminate problems.*
- *Equilibrium in the presence of sliding and rolling friction forces. Friction angle, friction cone, Euler's formula.*
- *Center of gravity of a rigid body. Formulas for coordinates and radius vector of the center of gravity. Methods for determining the center of gravity.*

Block 3. Kinematics and Mechanisms

- *Fundamental problem of point kinematics. Methods for specifying point motion. Classification of motion.*
- *Mechanisms as kinematic objects: links, kinematic pairs, crank, connecting rod, rocker, slider, slider-crank.*
- *Simple and translational motion of a rigid body. Main properties of translational motion.*
- *Rotational motion of a rigid body about a fixed axis: equations, relationships between angular displacement, velocity, and acceleration.*
- *Planar motion of a body: determination of point velocities and accelerations, velocity projection theorem.*
- *Instantaneous centers of velocity and acceleration. Position and application of ICVs and ICAs.*
- *Theorems on addition of velocities and accelerations in complex motion. Coriolis acceleration.*
- *Spherical motion of a body. Degrees of freedom. Euler angles. Euler–D'Alembert theorem.*
- *Motion of a free rigid body: equations of motion, degrees of freedom. Compound motion.*

Block 4. Dynamics and Kinetics

- *Momentum of a particle and a mechanical system. Impulse of force.*

- *Law of conservation of momentum of a mechanical system.*
- *Kinetic moment of a point and mechanical system relative to a center and axis. Theorems on changes in kinetic moment.*
- *Kinetic energy of a body and system in planar motion (König theorem). Theorem on kinetic energy change.*
- *Work of constant and variable forces. Work of friction forces during sliding and rolling.*
- *D'Alembert's principle. Inertia forces and principal vectors and moments of inertia forces.*
- *Principle of virtual displacements. General equation of system dynamics.*
- *Lagrange's equation of the second kind and its application for mechanical system motion.*

Block 5. Strength of Materials

- *Subject of strength of materials and main hypotheses. Classification of bodies, deformations, and stress factors.*
- *Internal force factors in bars. Method of sections.*
- *Types of bar deformations: tension-compression, shear, torsion, bending.*
- *Hooke's law for axial tension-compression. Young's modulus, Poisson's ratio.*
- *Allowable stresses. Strength conditions and calculations for tension-compression.*
- *Stress vector, stress tensor, law of shear stress parity. Principal stresses and planes.*
- *Superposition principle. Generalized Hooke's law. Stresses on inclined sections.*
- *Pure shear and torsion. Stress, potential energy of deformation, formulas for strength and stiffness.*
- *Bending deformation: types, differential relationships between distributed load, shear force, and bending moment. Construction of diagrams.*

Block 6. Biomechanics

- *General information about the human body. Center of mass and its motion. Inertial and somatic reference frames.*
- *Allometry and scaling in biomedical mechanics.*
- *Main types of deformations of biological materials and their mechanical properties.*
- *Rheology of biological materials: viscoelastic, viscoplastic, and elastic-viscous models. Two- and three-element rheological models.*
- *Human biomechanical system: links, biokinematic pairs, biokinematic chains. Determination of degrees of freedom.*
- *Mechanical properties of muscles, tendons, and joints. Muscle models, force–velocity relationship (Hill equation).*
- *Mechanics of blood vessels and biological fluids: Bernoulli, Newton, and Poiseuille equations. Viscosity, laminar flow, Reynolds number, stress, and flow velocity.*