



## BIOMEDICAL MECHANICS

### Working program of selective discipline (Silabus)

#### Requisites for basic discipline

Level of higher education	<i>First (bachelor's)</i>
Branch of knowledge	<i>16 Chemical and Bioengineering</i>
Specialty	<i>163 Biomedical Engineering</i>
Educational program	<i>Medical Engineering</i>
Discipline status	<i>Selective discipline</i>
Form of study	<i>full-time / day / mixed / remote</i>
Year of preparation, semester	<i>3th course, autumn semester</i>
The scope of discipline	<i>4 ECTS credits / 120 hours</i>
Semester control / Control measures	<i>fail assessment, Modular Test Work, term paper</i>
Lessons schedule	<i>According to the schedule on the site <a href="http://rozklad.kpi.ua/">http://rozklad.kpi.ua/</a></i>
Language of instruction	<i>English</i>
Information about course leader / teachers	<i><b>Lecturer:</b> PhD in Pedagogy, Associate Professor, Associate Professor of the Department of BME, Tetyana Bohdanova, e-mail: <a href="mailto:t.bogdanova@ill.kpi.ua">t.bogdanova@ill.kpi.ua</a> <b>Practical classes:</b> PhD in Pedagogy, Associate Professor, Associate Professor of the Department of BME, Tetyana Bohdanova, e-mail: <a href="mailto:t.bogdanova@ill.kpi.ua">t.bogdanova@ill.kpi.ua</a></i>
Course placement	<i><a href="https://classroom.google.com/c/Nzc1MDgyMjUyNjQ1?cjc=3eo4i3qp">https://classroom.google.com/c/Nzc1MDgyMjUyNjQ1?cjc=3eo4i3qp</a></i>

#### Distribution of hours

Semester	Lectures	Practical	Laboratory	Independent Work
<i>autumn semester</i>	<i>26</i>	<i>28</i>		<i>66</i>

#### Curriculum of the discipline

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

*The course "Biomedical Mechanics" is an elective discipline in the bachelor's program for the specialty 163 "Biomedical Engineering" and is aimed at deepening students' professional competencies in the analysis and modeling of mechanical processes in biological and biomedical systems. The course complements fundamental engineering training and provides an interdisciplinary link between mechanics, biology, and biomedical engineering.*

*The aim of the course is to develop students' ability to apply the laws and methods of biomedical mechanics to solve specialized engineering tasks and practical problems related to the study of the mechanical behavior of biological tissues, organs, human body systems, and biomedical devices, taking into account their structural and functional characteristics.*

*The course "Biomedical Mechanics" covers the basic concepts and laws of biomechanics, mechanics of deformable bodies and fluids, rheology, and continuum mechanics as applied to biological objects. Special attention is given to the analysis of the stress-strain state of biological tissues, the mechanics of bone and soft tissue structures, the mechanics of movement and interaction of organs and*

systems, as well as the specific mechanical behavior of biological materials under normal and pathological conditions.

During the course, students acquire skills to perform biomechanical analysis of biological and biomedical systems, construct simplified mathematical and rheological models of tissue mechanical behavior, interpret experimental and computational biomechanical characteristics, and use the acquired knowledge in the design, evaluation, and optimization of biomedical devices, implants, and engineering solutions.

### **Teaching methods**

Lectures employ explanatory-illustrative methods, problem-based learning, and interactive approaches. Practical classes utilize reproductive, partially exploratory, and interactive methods.

The study of the educational component enhances the following specialized (professional) competencies: (OPP was put into effect by the Rector's Order NON/434/2024 of 10.06.2024 p.):

**FK 03** - Ability to study and apply new methods and tools for analysis, modeling, design, and optimization of medical devices and systems.

**FK 05** - Ability to apply physical, chemical, biological, and mathematical methods in the analysis and modeling of the functioning of living organisms and biotechnical systems.

**FK 06** - Ability to effectively use tools and methods for analysis, design, calculation, and testing in the development of biomedical products and services

**FK 09** - Ability to identify, formulate, and solve engineering problems related to the interaction between living and non-living systems.

The study of the educational component strengthens the following program learning outcomes: (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 09** - Understand theoretical and practical approaches to the creation and application of artificial biological and biotechnical objects and materials for medical purposes.

**PRN 18** - Ability to utilize computer-aided design and drafting systems for developing the technological and hardware schematics of medical devices and systems, taking into account the specifics of their components.

**PRN 22** - Knowledge of general principles and structure of complex biological systems, including the human body and its functions from the perspective of a systemic approach and their utilization in biomedical engineering, as well as basic methods and tools used for quantitative assessment of physiological system functioning.

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

The course belongs to the elective educational components of the professional training cycle and is based on knowledge from the following disciplines: Human Anatomy and Physiology, Physics, Materials Science and Structural Materials, Quantitative Physiology, Mechanics and Biomechanics, and Biophysics.

The practical skills acquired and theoretical knowledge mastered during the study of this course can be further applied in the study of disciplines such as Biomedical Devices, Apparatuses, and Complexes, Human Physiological Parameters Monitoring Devices, as well as during pre-graduation internships and the preparation of the final qualification work.

### 3. The content of the discipline

#### Section 1. Biomechanics of the Musculoskeletal System and Locomotion

Topic 1.1. Introduction to Biomedical Mechanics

Topic 1.2. Kinematics of the Human Musculoskeletal System

Topic 1.3. Dynamics of the Musculoskeletal System

Topic 1.4. Biomechanics of Walking

Topic 1.5. Biomechanics of Muscle Contraction

Topic 1.6. Mechanical Properties and Rheology of Biological Materials

Topic 1.7. Theory of Thin-Walled Shells in Biomedical Mechanics

#### Section 2. Biomechanics of Internal Body Systems

Topic 2.1. Fundamentals of Mechanics of Biological Fluids

Topic 2.2. Biomechanics of the Cardiovascular System

Topic 2.3. Biomechanics of the Digestive System

### 4. Training materials and resources

#### Basic literature:

1. 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>.
2. Терещенко М.Ф. Біофізика: підручник / М. Ф. Терещенко, Г. С. Тимчик, І. О. Яковенко. - Київ: КПІ ім. Ігоря Сікорського, Вид-во «Політехніка», 2019. – 444 с.
3. Терещенко М.Ф. Біофізика. Практикум / М. Ф. Терещенко, Г. С. Тимчик, І.О. Яковенко - Київ: КПІ ім. Ігоря Сікорського, Вид-во «Політехніка», 2019. – 288 с.
4. Сливко Е. І. Медична і біологічна фізика: навч. посіб. / Е.І. Сливко, О. З. Мельнікова, О. З. Іванченко, Н. С. Біляк. – Запоріжжя, 2018. – 291 с.

#### Additional literature:

1. Методичні вказівки до виконання комплексної контрольної роботи з кредитного модуля «Біомедична механіка» для студентів напрямів підготовки 6.051402 «Біомедична інженерія», 6.050101 «Комп'ютерні науки», 6.051003 «Приладобудування» [Електронний ресурс] / НТУУ «КПІ»; уклад. Л.Д. Тарасова. – Електронні текстові дані (1 файл: 681 Кбайт). – Київ: НТУУ «КПІ», 2014. – 20 с. – Доступ: <http://ela.kpi.ua/handle/123456789/9960>
2. В. О. Кашуба, Ю.А. Попадюха. Біомеханіка просторової організації тіла людини: сучасні методи та засоби діагностики і відновлення. – К.: Центр учбової літератури, 2018. – 768 с.
3. Панченко С.П. 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.
4. Irving P. Herman. *Physics of the Human Body, Second Edition*. Springer International Publishing Switzerland 2006, 2016. – Режим доступу: [http://www.gaitlab.ir/books/gaitlab\\_ref\\_42\\_Irving\\_P.\\_Herman\\_auth.\\_Physics\\_of\\_the\\_Human\\_Body-Book.pdf](http://www.gaitlab.ir/books/gaitlab_ref_42_Irving_P._Herman_auth._Physics_of_the_Human_Body-Book.pdf)
5. Winter, David A. *Biomechanics and Motor Control of Human Movement, Fourth Edition* Copyright © 2009 John Wiley & Sons, Inc. ISBN: 978-0-470-39818-0. – Режим доступу: [https://edisciplinas.usp.br/pluginfile.php/4174628/mod\\_resource/content/2/David%20A.%20Winter-Biomechanics%20and%20Motor%20Control%20of%20Human%20Movement-Wiley%20%282009%29.pdf](https://edisciplinas.usp.br/pluginfile.php/4174628/mod_resource/content/2/David%20A.%20Winter-Biomechanics%20and%20Motor%20Control%20of%20Human%20Movement-Wiley%20%282009%29.pdf)

## Educational content

### 5. Methods of mastering the discipline (educational component)

№	Subject	Program Learning Outcomes (PRN)	Main Tasks	
			Control Activity	Deadline
1	Kinematics of the human musculoskeletal system	PRN 1, PRN 18	Practical work №1, №2	weeks 1–2
2	Dynamics of the human musculoskeletal system	PRN 1, PRN 9	Practical work №3, №4	weeks 3–4
3	Biomechanics of walking	PRN 1, PRN 18	Practical work №5, №6	weeks 5–6
4	Mechanical properties and rheology of biological materials	PRN 1, PRN 18	Practical work №7, №8	weeks 8–9
5	Theory of thin-walled shells in biomedical mechanics	PRN 1, PRN 22	Practical work №9	week 10
	Biomechanics of muscle contraction	PRN 1, PRN 9	Practical work №10	week 7
6	Fundamentals of fluid mechanics in the human body	PRN 1, PRN 18	Practical work №11	week 11
7	Biomechanics of the cardiovascular system	PRN 9, PRN 22	Practical work №12	week 12
8	Biomechanics of the digestive system	PRN 9, PRN 22	Practical work №13	week 13
9	Module control	PRN 1, PRN 9, PRN 18, PRN 22	Module control work №14	week 14

#### Lectures

##### Lecture topics:

#### 1. General issues of biomedical mechanics

Subject, research object, methods, and tasks of biomechanics. Main historical stages. Approaches to studying motion. General information about the human body. Standard human. Mass geometry. Directions, orientations, planes, and coordinate systems of the human body. System of fundamental physical quantities. Scaling laws. Allometric rules.

#### 2. Kinematics of the musculoskeletal system

Kinematic characteristics. Kinematic pair. Concept of degrees of freedom of the body. Classes of kinematic pairs. Kinematic pairs in the human body. Degrees of freedom of joints and their classification. Kinematic chain. Degrees of freedom of a kinematic chain. Degrees of freedom of biokinematic chains. Relationship between degrees of freedom and mobility.

#### 3. Dynamics of the musculoskeletal system: linear motion

Importance of dynamics in the study of the musculoskeletal system (MS). Main principles of MS dynamics. Forces in biomechanics. Non-contact forces. Ground reaction. Joint reaction force. Friction force. Fluid resistance. Muscle force. Elastic force. System of forces. Dynamic analysis. Influence of force applied over time. Centripetal force. Pressure.

#### 4. Dynamics of the musculoskeletal system: angular motion

Moment of force. Couple of forces. Newton's laws for rotational motion. Example of calculating

*the moment of inertia for point masses. Moment of inertia of human body segments. Parallel axis theorem. Newton's second law: angular acceleration. Angular momentum. Classes of levers in the human body. Stand-pull model. Conditions of static equilibrium. Application of static mechanics in medical equipment design. Fundamentals of dynamic analysis of human motion.*

### **5. Biomechanics of normal walking**

*Walking as a locomotor function. Main characteristics of normal walking. Functional organization of a step. Structure of the stance phase. Swing phase. Step cycle duration. Functional tasks during walking and balance. Determinants of walking. General features of normal walking. Biomechanics of three-plane foot motions. Biomechanics of the knee joint. Patellar biomechanical function. Physiological analysis of human walking. Measurement of external and internal forces. Analysis of ranges of motion during step organization. Energy efficiency of walking.*

### **6. Features of pathological walking**

*Energy expenditure during normal walking and on prostheses. Specific energy consumption when walking with different prosthesis designs. Walking features due to paralysis and paresis of the lower limbs. Walking features in patients with cerebral palsy. Walking features in joint mobility disorders. Walking on a prosthesis after unilateral lower limb amputation. Walking on prostheses after bilateral lower limb amputations.*

### **7. Mechanics of elastic biological materials**

*Main types of deformations experienced by the human body. Mechanical properties of elastic biological materials (Young's modulus, Poisson's ratio, strength limit, etc.). Features of mechanical properties of biological tissues and fluids. Components of biological tissues. Factors affecting the mechanical properties of biological tissues.*

### **8. Fundamentals of rheology**

*Rheological properties of materials illustrated by simple mechanical behavior models: elastic, viscous, and plastic; their characteristic features. Combined rheological models describing viscoelastic, elastoviscous, and viscoplastic properties of materials. Rules for composing rheological equations. Rheological behavior of biological materials exemplified by bone.*

### **9. Fundamentals of thin-walled shell theory**

*Membrane theory of shells. Stresses in shells with the shape of bodies of revolution. Laplace law. Meridional and circumferential normal stresses. Determination of stresses in spherical and cylindrical shells. Lamé equations. Calculation of liquid-filled shells. Example problem solutions.*

### **10. Mechanical properties and function of skeletal muscles**

*Biomechanical properties of muscles. Types of muscle contraction. Muscle structure. Skeletal muscle models. Muscle structure from the perspective of motor activity. Structure and mechanical properties of tendons. Auxiliary apparatus of muscles. Mechanisms of developing motor qualities. Muscle work modes. Hill equation. Weber and Bernoulli principles. Muscle coordination.*

### **11. Fundamentals of hemodynamics**

*Hydrostatics and hydrodynamics of biological fluids. Euler and Navier-Stokes differential equations. Flow regimes. Bernoulli equation for real and ideal fluids. Cavitation. Blood flow in the vascular system. Features of blood flow in curved vessels and branching vessels. Non-Newtonian fluids, their types and characteristics. Flow curves. Newton's law of viscous friction. Motion of viscous fluid in a tube. Distribution of internal shear stress in fluid flow.*

### **12. Biomechanics of the digestive system**

*Peristaltic transport and mixing. Mechanical phenomena in the digestive tract. Main functions of the stomach. Stomach as a continuous stirred chemical reactor. Main reactor types: plug flow reactor (PFR), batch reactor (BR), continuously stirred tank reactor (CSTR). Cascade of ideal CSTR reactors. Parameters of the CSTR stomach model. Key formulas.*

## **Practical works**

1. Mass geometry of body segments: determination of the weight of human body segments and the position of their centers of mass using multiple regression equations; determination of joint coordinates and centers of mass of body segments in different postures.
2. Kinematics of the musculoskeletal system: determination of the coordinates of the overall center of mass (OCM) of the human body in different positions, central moment of inertia of body segments, moment of inertia of the human body relative to the axis of rotation in different postures.
3. Biodynamic analysis of human movements: biomechanical analysis of squats.
4. Modeling loads in the elbow joint when using a prosthetic arm.
5. Designing the trajectory of the human center of mass during walking and determination of walking energy efficiency.
6. Kinematic analysis of movements during walking: modeling of a human step.
7. Mechanics of elastic biological materials.
8. Rheological models of biological tissues.
9. Fundamentals of thin-walled shell theory.
10. Biomechanics of muscle contraction.
11. Application of Bernoulli's equation in biomechanics.
12. Mechanical properties of blood vessels.
13. Mechanics of the gastrointestinal tract.
14. Modular control work.

## 6. Independent student work

No s/n	Types of Independent Study	Number of Hours
1	Preparation for lectures and practical classes	26
2	Completion of assignments related to practical classes	26
3	Preparation for the modular assessment test	4
4	Writing a term pape	10
Total		66

In the course “**Biomedical Mechanics**”, an individual assignment in the form of a term paper is planned. The main goal of the term paper is to deepen and expand students’ theoretical knowledge of selected topics of the course, and to gain experience in independent work with academic and scientific literature. The term paper is completed according to the requirements and within the deadlines specified by the instructor.

### **Suggested topics for term papers:**

1. Biomechanics of human walking: modern research methods
2. Comparative biomechanics of running and walking
3. Biomechanics of jumps in everyday human activity
4. Biomechanical aspects of balance and falls in the elderly
5. Application of biomechanics in rehabilitation after musculoskeletal injuries
6. Biomechanics of movements in aquatic environments (adaptive swimming)
7. Bone biomechanics: effect of physical loads on bone strength
8. Cartilage and joint biomechanics in health and pathology
9. Spine biomechanics: physiology and pathology
10. Foot biomechanics: role in forming correct gait
11. Modeling loads in the knee joint
12. Biomechanics of lower limb prostheses
13. Biomechanics of upper limb prostheses

14. *Biomechanics of orthoses and their role in rehabilitation*
15. *Mechanical properties of skeletal muscles in health and pathology*
16. *Biomechanics of masticatory muscles and jaw prosthesis development*
17. *Biomechanics of cardiac muscle function*
18. *Biomechanics of respiratory muscles*
19. *Biomechanics of soft tissues in prosthetics*
20. *Biomechanics of skin and artificial coverings in prostheses*
21. *Biomechanics of blood circulation: modeling blood flow in vessels*
22. *Biomechanics of heart valves*
23. *Biomechanics of the lymphatic system*
24. *Biomechanics of gastrointestinal peristalsis*
25. *Viscous properties of biological fluids*
26. *Non-Newtonian properties of blood*
27. *Application of 3D printing in prosthetic biomechanics*
28. *Biomechanics of hip joint implants*
29. *Biomechanics of knee joint implants*
30. *Biomechanics of dental implants*
31. *Biomechanics of spinal fixators*
32. *Biomechanics of intraocular lenses*
33. *Biomechanics of hearing implants*
34. *Biomechanics of exoskeletons*
35. *Biomechanics of robotic prostheses*
36. *Virtual reality in biomechanical movement research*
37. *Biomechanics of wearable sensors for motion monitoring*
38. *Modeling in biomechanics: finite element methods*
39. *Biomechanics in nanomedicine: mechanics of cells and membranes*
40. *Biomechanics of tissue engineering: creating artificial organs*

### **Term Paper Guidelines**

The term paper for the course **“Biomedical Mechanics”** should follow the structure below:

#### **Title Page**

The title page must include:

- *Name of the university*
- *Name of the faculty*
- *Name of the department*
- *Name of the course*
- *Title of the term paper*
- *Level of higher education, name of the specialty, name of the educational program*
- *Student’s full name, year of study, academic group number, year*

#### **Table of Contents**

The title page is followed by a detailed table of contents, which should highlight the introduction, main sections, subsections (if needed), conclusion, and list of references. Page numbers for each structural element should be indicated on the right.

#### **Introduction**

The introduction should:

- *Justify the relevance of the chosen topic*
- *Assess the current state of research on the problem*
- *Formulate the aim and objectives of the term paper*

- Provide a brief overview of the literature and sources used

### **Main Body**

The main body includes an analytical review of modern sources (at least 5) and a synthesis of information on the chosen topic. The term paper should be written in an impersonal style (e.g., “it was analyzed,” “it was demonstrated”). The presentation of material must be clear, precise, and include necessary explanations with references to information sources. References should be indicated by a sequential number in square brackets, e.g., “...in the collection of problems [3, p.34] ...”.

### **Conclusion**

The conclusion should cover the following aspects:

- Assess the extent to which the aim and objectives of the work have been achieved
- List and briefly describe known approaches to the examined problem
- Highlight new aspects for further research
- Identify what is valuable in the reviewed works and requires additional analysis

### **References**

The list of references should follow current citation rules. If information is taken from the Internet, it should be cited like conventional literature: author, title of the article, followed by the website address.

### **Formatting Requirements**

Standard A4 sheet

Margins: left – 30 mm, right – 15 mm, top – 20 mm, bottom – 20 mm

Font: Times New Roman, size 14 pt

Line spacing: 1.5

First-line indent: 1.25 cm

Justified alignment

No hyphenation of words

Figures and tables should have captions and numbering consistent with the section number

Each structural element of the paper should start on a new page

Titles of structural elements should be centered, without a period, underlining, and separated from the text by three line spacings

### **Length**

There is no strict requirement for the number of pages. The paper should fully reveal the topic and include all necessary structural elements. Recommended length: 10–25 pages.

### **Evaluation Criteria**

Relevance to the chosen topic

- Quality of formatting and completeness of structural elements
- Originality of the material
- Level of mastery of theoretical material presented in the paper
- Term papers are not checked for plagiarism but must comply with academic integrity standards. In case of academic dishonesty, the work will not be accepted.

### **Deadline**

The term paper must be submitted by the 15th week of the semester.

## **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.

### Grading System (Ongoing Control):

No.	Control Activity	%	Weight	Quantity	Total
1	Completion and defense of practical assignments	52	4	13	52
2	Modular Control Work (MCW)	20	20	1	20
3	term paper	28	28	1	28
4	assessment	72	72	1	72
Total		100			100

**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		8th week	14th week
Conditions for a positive result in Calendar Control	Ongoing rating	≥ 14,4 points	≥ 31,2 points
	Completion of practical assignments	No No 1-12	+
		No No 13-26	-
	Modular Control Work (MCW)	Graded MCW	-
term paper	Graded term paper	-	

### Semester Control (Final Assessment)

Mandatory condition for admission to the test	Criterion
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1	Current rating	$RD \geq 40$
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 assessment 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)

**Approximate list of questions and tasks for preparation for the modular test and pass/fail assessment**

1. *Approaches to the study of movement in biomechanics.*
2. *The concept of the “standard human” in biomedical mechanics.*
3. *Mass geometry of the human body and its significance in biomechanical research.*
4. *Anatomical planes, directions, and coordinate systems of the human body.*
5. *The system of basic physical quantities in biomechanics.*
6. *Scaling laws and allometric rules in biomedical mechanics.*
7. *Kinematic characteristics of movement and their biomechanical meaning.*
8. *Kinematic pairs and degrees of freedom of the human body.*
9. *Kinematic chains of the musculoskeletal system and their classification.*
10. *The role of dynamics in the study of the human musculoskeletal system.*
11. *Forces in biomechanics: classification and examples of action in the human body.*
12. *Ground reaction force and joint reaction force in biomechanical models.*
13. *Effect of a force applied over time. Impulse of force.*
14. *Moment of force and couple of forces in biomechanics.*
15. *Newton’s laws for rotational motion.*
16. *Moment of inertia of human body segments and the parallel axis theorem.*
17. *Levers in the human body and their biomechanical classification.*
18. *Conditions of static equilibrium and their application in biomedical engineering.*
19. *Biomechanics of normal gait: phases of the step and their functional features.*
20. *Determinants of efficient gait and energy efficiency of locomotion.*
21. *Biomechanical features of triplanar movements of the foot and the knee joint.*
22. *Features of pathological gait in disorders of the musculoskeletal system.*
23. *Energy expenditure during walking with lower-limb prostheses.*
24. *Mechanical properties of elastic biological materials.*
25. *Basic rheological models of biological tissues and their application.*
26. *Fundamentals of the theory of thin-walled shells in biomedical mechanics.*
27. *Fundamentals of hemodynamics: blood flow regimes and the Bernoulli equation.*
28. *Biomechanical models of the cardiovascular and digestive systems of the human body.*