



# Biothermodynamics and mass transfer

## Working program of educational discipline (Syllabus)

### Requisites of the Course

<b>Cycle of Higher Education</b>	<i>First (bachelor's)</i>
<b>Branch of knowledge</b>	<i>16 Chemical and Bioengineering</i>
<b>Specialty</b>	<i>163 Biomedical Engineering</i>
<b>Educational program</b>	<i>Medical Engineering</i>
<b>Course status</b>	<i>Mandatory discipline</i>
<b>Mode of study</b>	<i>full-time / day / mixed / remote</i>
<b>Year of study/Semester</b>	<i>1<sup>st</sup> year (spring semester)</i>
<b>ECTS workload</b>	<i>4 ECTS credits / 120 hours</i>
<b>Testing and Assessment</b>	<i>Final Test, Module Test , Homework</i>
<b>Course schedule</b>	<i>According to the schedule on the site <a href="http://rozklad.kpi.ua/">http://rozklad.kpi.ua/</a></i>
<b>Language of instruction</b>	<i>English</i>
<b>Information about course supervisor / teachers</b>	<p><b><u>Lecturer:</u></b> Kalashnikova Larysa, Associate Professor of BME, PhD in Biological Sciences, e-mail – <a href="mailto:doc_hom2000@yahoo.com">doc_hom2000@yahoo.com</a></p> <p><b><u>Practical:</u></b> Maryna Sychyk, Associate Professor, Department of BMI PhD (Engineering), E-mail: <a href="mailto:marina.sychik@gmail.com">marina.sychik@gmail.com</a>, <a href="mailto:sychykm@gmail.com">sychykm@gmail.com</a> Telegram: <a href="https://t.me/Maryna_Sychyk">https://t.me/Maryna_Sychyk</a></p>
<b>Course placement</b>	<i>Platform «Sikorsky» - course "Biothermodynamics and Mass Transfer" <a href="https://do.ipokpi.ua">https://do.ipokpi.ua</a></i>

### Distribution of hours

Semester	Lectures	Practical	Laboratory	Self-study
<i>spring semester</i>	22	26		72

### Curriculum of the discipline

#### 1. Course description, goals, objectives, and learning outcomes

Course "**Biothermodynamics and Mass Transfer**" belongs to the cycle of professional training of the bachelor's degree curriculum

The discipline forms a systematic knowledge of the connection and conversion of nutrients, and the release of heat, energy conversion in the interaction of a living organism with the environment.

The purpose of the discipline "**Biothermodynamics and mass transfer**" forms in students the ability to establish a connection between various facts and phenomena and using the methods of biothermodynamics.

The Course "**Biothermodynamics and mass transfer**" belongs to the cycle of Mandatory discipline of professional training. It is designed for first-year bachelors who do not have a systematic understanding of the specialty.

#### Own the basics

Course forms students' system knowledge and skills

To study the discipline "**Biothermodynamics and Mass Transfer**" you need:

*-skills:* knowledge of the basics of thermodynamic methods as well as skills of determining thermodynamic parameters and characteristic functions; knowledge of ways and conditions of energy conversion in the process of metabolism, to analyze ways of thermoregulation by an organism and ways of thermoregulation.

*-competencies:* ability to perform calculations of thermodynamic parameters of physicochemical processes when considering their physicochemical essence, as well as the interaction of a living system with the environment; to abstract thinking, analysis and synthesis; ability to communicate in the state language both orally and in writing; skills of using information and communication technologies; ability to search, process and analyze information from various sources.

**General competencies** (The EP was put into effect by the Rector's Order. HOH/434/2024 from 10.06.2024 y.):

**GC 01** - Ability to apply knowledge in practical situations (**enhancement**)

**GC 06** - Ability to search, process and analyze information from various sources. (**enhancement**)

**Special (professional) competencies** ((The EP was put into effect by the Rector's Order. HOH/434/2024 from 10.06.2024 y.):

**PC 05** Ability to apply physical, chemical, biological, and mathematical methods in the analysis and modeling of the functioning of living organisms and biotechnical systems (**enhancement**)

**The program learning outcomes after studying the discipline "Introduction to the profession" are** (The EP was put into effect by the Rector's Order. HOH/434/2024 from 10.06.2024 y.):

**PLO 09** Understand theoretical and practical approaches to the creation and application of artificial biological and biotechnical objects and materials for medical purposes (**enhancement**)

**PLO 17** Application of knowledge in chemistry and bioengineering to create, synthesize, and apply artificial biotechnical and biological objects (**enhancement**)

**PLO 18** Understanding of fundamental-applied, medical-physical, and physico-chemical principles governing the functioning of biological objects, as well as bioengineering fundamentals of technologies and equipment for researching human body processes (**enhancement**)

**PLO 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 (**enhancement**)

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

The discipline "Biothermodynamics and Mass Transfer" belongs to the cycle of professional training and has an interdisciplinary nature. It integrates according to its subject knowledge from other disciplines: Quantitative Physiology, Physics, Biophysics.

According to the structural and logical scheme of the specialist training program, the discipline "Biothermodynamics and Mass Transfer" is closely related to other disciplines of professional training: Medical medical equipment; Methods and means of diagnosing human pathology, Physiotherapeutic medical devices; Undergraduate practice and Diploma design.

## **3. Course Overview**

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

### **Section1. The main characteristics of biothermodynamics.**

**Topic 1.1.** Fundamentals and Basic Principles of the Systems Approach.

Concept of a system. Classification and characteristics of a system as a whole. Features of a living organism as a thermodynamic system. Postulates of biothermodynamics.

**Topic 1.2.** Thermodynamics of Biological Processes.

*Laws of energy conservation. Concepts of work, free energy, and total energy of a system. Thermodynamics of biological processes. Determination of enthalpy and standard free energy of a chemical reaction.*

**Topic 1.3. Main Types of Heat Transfer in the Body.**

*Temperature field and temperature gradient. Thermoregulation and its control systems. Heat balance of the body. Regulation of body temperature.*

**Topic 1.4. The Second Law of Thermodynamics.**

*Clausius theorems, entropy, the second and third formulations of the second law of thermodynamics. Thermodynamic potentials and their biological significance. Thermodynamic stability theory; necessary and sufficient conditions for different systems.*

**Topic 1.5. Nonequilibrium Thermodynamics**

*Hypothesis of local equilibrium. Transport theorem and entropy balance equations. Entropy production.*

**Section 2. The main ways of heat and mass transfer in living systems.**

**Topic 2.1** *Fundamentals of hemodynamics. The work of the heart. Biophysical features of blood rheology.*

**Topic 2.2.** *Mass transfer in the lungs and tissues*

**Topic 2.3.** *Fundamentals of diffusion in a living organism. Membrane mass transfer.*

**Topic 2.4.** *Water-electrolyte balance of the body. Mechanisms of sorption and desorption*

**Topic 2.5.** *Beginning of gap connections in energy mass transfer*

**4. Coursebooks and teaching resources**

**Basic:**

1. «Біотермодинаміка та масоперенос»: навчальний посібник методичних матеріалів для самостійної роботи здобувачів ступеня бакалавра за освітньою програмою «Медична інженерія» спеціальності 163 - «Біомедична інженерія» / КПІ ім. Ігоря Сікорського; уклад. Л.Є. Калайнікова, М.М. Сичик; КПІ ім. Ігоря Сікорського. – Київ: КПІ ім. Ігоря Сікорського», 2021. – 64 с
2. Медична і біологічна фізика: підручник / Личковський Е.І., Пайкуш М.А., Вісьтак М.В., Фафула Р.В. Львів: «Новий Світ – 2000», 2021. – 319 с.
3. Посудін Ю.І. Біофізика: підручник. - Ліра-К, 2021 – 472с.
4. ТЕРМОДИНАМІКА БІОЛОГІЧНИХ ПРОЦЕСІВ. НАВЧАЛЬНИЙ ПОСІБНИК. // укл. О. І. Доценко. – Вінниця: ДонНУ імені Василя Стуса, 2019. –103 с.
5. Шинкарик М.М., Кравець О.І. Основи теплотехніки: навч. посібник. – Тернопіль: ФОП Паляниця В.А., 2024. 132 с.
6. Davidovits P. Physics in biology and medicine. 5-th ed. – Amsterdam: Elsevier Academic Press, 2019. – 377 p.
7. Kaksis Aris BioThermodynamics Riga University, 2021.  
<http://aris.gusc.lv/BioThermodynamics/BioThermodynamics.pdf>

**Supplementary:**

1. Біофізика. Фізичні методи аналізу та метрологія: під 663 ручник / Е. І. Личковський, В. О. Тіманюк, О. В. Чалий [та ін.]; за ред. Е. І. Личковського, В. О. Тіманюка. Вінниця : Нова Книга, 2014.-464 с.
2. Єршов Ю.А. Біотехнічні системи медичного призначення: підручник. -2018.  
<https://stud.com.ua/180525/tehnika/peredmov>
3. APPLICATION OF THERMODYNAMICS TO BIOLOGICAL AND MATERIALS SCIENCE/ Edited by Tadashi Mizutani 2011.- 640 p.  
[http://www.issp.ac.ru/ebooks/books/open/Application\\_of\\_Thermodynamics\\_to\\_Biological\\_and\\_Materials\\_Science.pdf](http://www.issp.ac.ru/ebooks/books/open/Application_of_Thermodynamics_to_Biological_and_Materials_Science.pdf)
4. **Biochemical Thermodynamics**  
[https://www.chem.uwec.edu/chem406\\_f06/pages/lecture\\_notes/lect03/Atkins-Ch1.pdf](https://www.chem.uwec.edu/chem406_f06/pages/lecture_notes/lect03/Atkins-Ch1.pdf)
5. Dadan Rosana Biophysics: An Introduction, 2012. - 38 p.  
<http://staffnew.uny.ac.id/upload/132058092/pendidikan/biophysics-book.pdf>
6. Dillon Patrick F. Biophysics A Physiological Approach, 2016.- 314p  
<https://epdflibrary.com/map2/1107001447>

- 7 *Engineering Thermodynamics Summary of topics from University of Washington course ME323: Engineering Thermodynamics taught Winter 2016 by Prof. Dayong Gao (DXG) compiled by Michael C. McGoodwin (MCM). Content last updated 6/19/2016*  
<https://www.mcgoodwin.net/pages/thermodynamics.pdf>
- 8 *Kappen Bert Introduction to biophysics, Department of Biophysics Radboud University Nijmegen February 7, 2008*  
<http://www.snn.ru.nl/~bertk/biofysica/handouts.pdf>
- 9 *Law of Thermodynamics*  
[https://bio.libretexts.org/Bookshelves/Cell\\_and\\_Molecular\\_Biology/Book%3A\\_Cells\\_-\\_Molecules\\_and\\_Mechanisms\\_\(Wong\)/03%3A\\_Bioenergetics\\_-\\_Thermodynamics\\_and\\_Enzymes/3.01%3A\\_The\\_Laws\\_of\\_Thermodynamics](https://bio.libretexts.org/Bookshelves/Cell_and_Molecular_Biology/Book%3A_Cells_-_Molecules_and_Mechanisms_(Wong)/03%3A_Bioenergetics_-_Thermodynamics_and_Enzymes/3.01%3A_The_Laws_of_Thermodynamics)
- 10 *Thermodynamics of Biological Systems*  
<http://core.ecu.edu/biol/evansc/PutnamEvans/5800PDF/Thermodynamics.pdf>
- 11 *Urs von Stockar J. Biothermodynamics of live cells: a tool for biotechnology and biochemical engineering J. Non-Equilib. Thermodyn./Communicated by J. M. Rubi, Barcelona, Spain, and J. U. Keller, Siegen, Germany, 2010.-P. 415–475. DOI 10.1515/JNETDY*  
<https://core.ac.uk/download/pdf/85213732.pdf>

### Educational content

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

№ s/n	Subject	Program learning outcomes	The main tasks	
			Control measure	Термін виконання
Section 1. Basic Characteristics of Biothermodynamics				
1	<p><b>Topic 1.1.</b> Fundamentals and Basic Principles of the Systems Approach. Concept of a System.</p> <p><b>Lecture 1.</b> <i>Classification and Characteristics of a System as a Whole. Features of a Living Organism as a Thermodynamic System. Postulates of Biothermodynamics.</i></p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical patterns of functioning of biological objects, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Additionally, improvement of knowledge on general information and principles of the structure of complex biological systems, including the human body, understanding the human organism and its functions from a systems approach perspective, and their application in biomedical engineering, as well as the main methods and tools used for the quantitative assessment of physiological system functioning.</p>	PLO 18	Practical work 1	1 <sup>st</sup> week
2	<p><b>Topic 1.2. Thermodynamics of Biological Processes.</b></p> <p>Law of energy conservation. Concepts of work, free energy, and total energy of a system. Thermodynamics of biological processes. Determination of enthalpy and standard free energy of a chemical reaction. Hess's Law.</p> <p><b>Lecture 2:</b> Concepts of work, free energy, and total energy of a system. Thermodynamics of biological processes.</p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical principles of the functioning of biological objects, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Improvement of knowledge about general concepts and</p>	PLO 18 PLO 22	Practical work 2-3	2 <sup>nd</sup> week

	principles of the structure of complex biological systems, including the human body; understanding human body functions from a systems approach perspective and their application in biomedical engineering; and mastering basic methods and tools used for quantitative assessment of physiological system functioning.			
3	<p><b>Topic 1.3.</b> Temperature Field and Temperature Gradient. Concept of a blackbody.</p> <p><b>Lecture 2:</b> Key characteristics of heat and mass transfer. Laws of thermal radiation.</p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical principles of the functioning of biological objects, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Improvement of knowledge about general concepts and principles of the structure of complex biological systems, including the human body; understanding human body functions from a systems approach perspective and their application in biomedical engineering; and mastering basic methods and tools used for quantitative assessment of physiological system functioning.</p>	<p><i>PLO 18</i> <i>PLO 22</i></p>	<i>Practical work 3</i>	<i>3<sup>rd</sup> week</i>
4	<p><b>Topic 1.4. Main Types of Heat Transfer in the Body. Physiological and Physical Regulation</b></p> <p><b>Lecture 3:</b> Thermoregulation and its control systems. Heat balance of the body. Body temperature regulation. Thermopathology.</p> <p><b>Practical Classes:</b> Discussion aimed at understanding the fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for studying human body processes. Application of bioengineering knowledge for the creation and use of artificial biotechnical systems.</p> <p>Enhancement of knowledge regarding general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastering the basic methods and tools used for quantitative assessment of physiological system functioning.</p>	<p><i>PLO 18</i> <i>PLO 22</i></p>	<i>Practical work 4</i>	<i>4<sup>th</sup> week</i>
5.	<p><b>Topic 1.5.</b> The Second Law of Thermodynamics. Clausius theorems, entropy, the second and third formulations of the second law of thermodynamics. Thermodynamic potentials and their biological significance. Thermodynamic stability theory; necessary and sufficient conditions for different systems. Main thermodynamic potentials and their relevance to biological systems.</p> <p><b>Lecture 5:</b> The second law of thermodynamics. Clausius theorems. Concept of entropy. Thermodynamic potentials.</p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in</p>	<p><i>PLO 18</i> <i>PLO 22</i></p>	<i>Practical work 5</i>	<i>5<sup>th</sup> week</i>

	biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning.			
	<p><b>Topic 1.6.</b> Nonequilibrium Thermodynamics: Hypothesis of local equilibrium, transport theorem, and entropy balance equations; entropy production.</p> <p><b>Lecture 6:</b> Determination of driving forces and generalized rates of biological processes from the perspective of energetics.</p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning.</p>	<p>PLO 17 PLO 18 PLO 22</p>	Practical work 6	6 <sup>th</sup> week
<b>Section 2. Main Pathways of Heat and Mass Transfer in Living Systems</b>				
6.	<p><b>Topic 2.1.</b> Properties of Fluids. Newton's law of viscosity. Newtonian and non-Newtonian fluids.</p> <p><b>Lecture 7:</b> Fundamentals of hemodynamics. Viscosimetry. Classification and applications of viscometers.</p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning.</p>	<p>PLO 17 PLO 18 PLO 22</p>	Practical work 7	7 <sup>th</sup> week
7	<p><b>Topic 2.2.</b> Fundamentals of Diffusion in the Living Organism. Mass transfer across the cell membrane.</p> <p><b>Lecture 8:</b> Basic laws of mass transfer through semipermeable barriers.</p> <p><b>Practical Classes:</b> Study of fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for investigating human body processes.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning.</p>	<p>PLO 09 PLO 17 PLO 18 PLO 22</p>	Practical work 8	8 <sup>th</sup> week
8.	<p><b>Topic 2.3.</b> Biophysical Features of Blood Rheology. Fundamentals of hemodynamics. Heart function.</p> <p><b>Lecture 9:</b> Heart function. Recording and support of heart activity. Biophysical characteristics of heart operation.</p>	<p>PLO 09 PLO 17 PLO 18 PLO 22</p>	Practical work 9	9 <sup>th</sup> week

	<p><b>Practical Classes:</b> Discussion aimed at understanding fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for studying human body processes. Application of bioengineering knowledge for the creation and use of artificial biotechnical systems.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning.</p>			
9	<p><b>Topic 2.4.</b> Mass Exchange in the Lungs and Tissues</p> <p><b>Lecture 10:</b> Biophysical features of mass transfer in the lungs. Biophysical fundamentals of lung function.</p> <p><b>Practical Classes:</b> Discussion aimed at understanding fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for studying human body processes. Application of bioengineering knowledge for the creation and use of artificial biotechnical systems.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning</p>	<p>PLO 09 PLO 17 PLO 18 PLO 22</p>	Practical work 10	10 <sup>th</sup> week
10	<p><b>Topic 2.5.</b> Water-Electrolyte Balance of the Body. Physiology of the Kidneys. Sorption and desorption. The role of feedback mechanisms in energy and mass transfer in biological systems.</p> <p><b>Lecture 11:</b> Mechanisms of sorption and desorption in kidney function.</p> <p><b>Practical Classes:</b> Discussion aimed at understanding fundamental and applied, medical-physical, and physico-chemical principles of biological system functioning, as well as bioengineering foundations of technologies and equipment for studying human body processes. Application of bioengineering knowledge for the creation and use of artificial biotechnical systems.</p> <p>Enhancement of knowledge of general concepts and principles of complex biological system structures, including the human body; understanding human body functions from a systems approach and their application in biomedical engineering; and mastery of basic methods and tools used for quantitative assessment of physiological system functioning.</p>	<p>PLO 17 PLO 18 PLO 22</p>	Practical work 11	11 <sup>th</sup> -week
10.	Submission esse		Practical work 12	12 <sup>th</sup> week
11.	Module test		Practical work 13	13 <sup>th</sup> week
12	Abstract			14 <sup>th</sup> – 15 <sup>th</sup> week
13	Final tests			Final tests pass



## Hourly Distribution of Classes

Lecture Topic	Lecture		Practical Work		Assessment
	Weeks	Hours	Weeks	Hours	
Section 1: Basic Characteristics of Biothermodynamics					
Topic 1.1. Fundamentals and Basic Principles of the Systems Approach. Concept of a system. Classification and characteristics of a system as a whole. Features of a living organism as a thermodynamic system. Postulates of biothermodynamics.	1	2	1	2	Practical work №1
Topic 1.2. Thermodynamics of Biological Processes. Law of energy conservation. Concepts of work, free energy, and total energy of a system. Thermodynamics of biological processes. Determination of enthalpy and standard free energy of a chemical reaction. Hess's Law..	2	2	2	2	Practical work №2
Topic 1.3. Temperature Field and Temperature Gradient. Concept of a blackbody.	3	2	3	2	Practical work №3 Test №1
Topic 1.4. Main Types of Heat Transfer in the Body. Physiological and physical regulation.	4	2	4	2	Practical work №4
Тема 1.5. The Second Law of Thermodynamics in Biological Systems. Fundamental thermodynamic equation for biological systems. Main thermodynamic potentials. Thermodynamic stability theory; necessary and sufficient conditions for different systems...	5	2	5	2	Practical work №5
Topic 1.6. Nonequilibrium Thermodynamics: Hypothesis of local equilibrium; transport theorem and entropy balance equations; entropy production.	6	2	6	2	Practical work № 6
Section 2. Main Pathways of Heat and Mass Transfer in Living Systems					
Topic 2.1. Properties of Fluids. Newton's law of viscosity. Newtonian and non-Newtonian fluids.	7	4	7	2	Practical work № 7
Topic 2.2. Fundamentals of Diffusion in the Living Organism. Mass transfer across the cell membrane.	8	2	8	2	Practical work № 8 Test 2
Topic 2.3. Biophysical Features of Blood Rheology. Fundamentals of Hemodynamics. Heart Function.	9	2	9	2	Practical work №9
Topic 2.4. Mass Exchange in the Lungs and Tissues	10	2	10	2	Practical work №10
Topic 2.5. Water-Electrolyte Balance of the Body. Physiology of the Kidneys.	11	2	11	2	Practical work №11 Test 3
Submission esse			12	2	Practical work №12
Module Control Work			13	2	Practical work №13 (MCW)
Esse Report Defense			14-15	4	Esse
Credit			16	(2)	Final tests pass



## 6. Self-study

### *Independent Work Includes:*

*Preparation for lectures and practical classes; completion and defense of a research paper; preparation for the module control work; preparation for the final credit (assessment), etc.*

### *6.1. Types of Independent Work*

№	Types of Independent Work	Number of Hours (IWS*)
1	Review of lecture material and study of topics assigned for independent work	16
2	Preparation for practical classes	24
3	Preparation for the module control work	10
4	Completion of the research paper	12
5	Preparation for the final credit (assessment)	10
<b>Total</b>		<b>72</b>

### *Distribution of Student Independent Work Hours by Topic*

№	Topics and Questions for Self-Study with References	Self-Study Hours (CPC)
1	Fundamentals and Basic Principles of the Systems Approach. Principles, Main Stages and Methods of Systems Analysis. Concept of a System, Element, Environment, Functions, State, Process. <b>Questions for Self-Study:</b> Fundamentals and basic principles of the systems approach; concept of a thermodynamic system; characteristics of a thermodynamic system; features of a living organism as a thermodynamic system. [1, 2, 4]	2
2	Concepts of Work, Free and Total Energy of a System. Concept of Internal Energy and Ways of Its Change; Concept of Work and Heat. Main Signs of Life. Energy of Life. Functional and Networked Structure and Dynamics. <b>Questions for Self-Study:</b> Concept of internal energy and ways of its change; concept of work and heat; main signs of life; energy of life. [1, 2, 4, 8-9]	4
3	Basic Concepts of Thermodynamics. Concept of a Biothermodynamic System and Its Characteristics. Classification and Characteristics of a System as a Whole. Thermodynamic States of the System. <b>Questions for Self-Study:</b> Determination of enthalpy and standard free energy of a chemical reaction; heat effect of the reaction; postulates of biothermodynamics. [1, 2, 4, 9, 10]	2
4	Main Types of Heat Transfer in the Body. Physiological and Physical Regulation. <b>Questions for Self-Study:</b> Heat balance of the body; regulation of body temperature; thermal radiation of the living organism; concept of a black body. [1-5, 8-9]	4
5	Second Law of Thermodynamics for Biological Systems. Main Thermodynamic Equation for Biological Systems. Major Thermodynamic Potentials. <b>Questions for Self-Study:</b> Thermodynamic theory of stability; necessary and sufficient conditions for various systems. [1, 2, 4, 5, 9]	4
6	Non-Equilibrium Thermodynamics: Hypothesis of Local Equilibrium, Transfer Theorem and Entropy Balance Equation, Entropy Production. <b>Questions for Self-Study:</b> Thermoregulation and its control systems; thermopathology. [3, 4, 9]	4
7	Properties of Fluids. Newton's Law of Viscosity. Newtonian and Non-Newtonian Fluids. <b>Questions for Self-Study:</b> Calorimetry of biological and biochemical processes. [4, 6, 7]	4
8	Basics of Diffusion in the Living Organism. Mass Transfer through the Cell Membrane. <b>Questions for Self-Study:</b> Diffusion processes in biological systems. [2-6]	4
9	Biophysical Features of Blood Rheology. Basics of Hemodynamics. Heart Function. <b>Questions for Self-Study:</b> Determination of driving forces and generalized blood velocities from the perspective of rheology laws. [3-6, 9-10]	4
10	Mass Exchange in Lungs and Tissues. <b>Questions for Self-Study:</b> Study of mechanical characteristics of the lungs and elasticity of the bronchopulmonary system. [6-10]	4
11	Water-Electrolyte Balance of the Body. Kidney Physiology. <b>Questions for Self-Study:</b> Study of osmosis, sorption, and desorption processes in different parts of the system. [4, 6-10]	4

№	Topics and Questions for Self-Study with References	Self-Study Hours (CPC)
12	Module Control Work	10
13	Essay	12
14	Final Credit	10
<b>Total</b>		<b>72</b>

*One of the main types of semester control during the mastering of the discipline "**Biothermodynamics and Mass Transfer**" is the writing of an abstract.*

*Abstract - a type of written work, a statement on a particular topic, information for which is collected from various sources using current literature on the topic. The abstract is a form of testing the student's knowledge on the topics of the course. Abstract is an independent educational and scientific research of a student, which is performed on a specific topic, which is carried out outside the educational process.*

***Approximate subject of reports:***

- 1. Features of biological organisms as thermodynamic systems*
- 2. Thermodynamics of muscle contraction*
- 3. Characteristics of the biosystem as a thermodynamic system.*
- 4. Heat and mass transfer of man with the environment.*
- 5. The concept of enthalpy. Hesse's thermal law.*
- 6. Thermodynamic potentials - their characteristics and biological role.*
- 7. The role of thermodynamics in solving biomedical problems.*
- 8. Methods of colorimetry.*
- 9. Entropy of the biosystem.*
- 10. Destruction of energy in nature*
- 11. Thermodynamics of open (biological) systems*
- 12. Thermodynamic characteristics of transport of substances across the membrane*
- 13. Features of filtration*
- 14. Fundamentals of hemodynamics.*
- 15. Basic laws of blood flow in blood vessels.*
- 16. Human thermoregulation*
- 17. Thermal comfort and energy balance of the person.*
- 18. Thermodynamics of muscle contraction*
- 19. The first law of thermodynamics in biosystems*
- 20. Characterization of the biosystem as a thermodynamic system*
- 21. The second law of thermodynamics as applied to biosystems*
- 22. Heat and mass transfer of a person with the environment*
- 23. The concept of enthalpy. Thermal law of Hesse.*
- 24. Thermodynamic potentials - their characteristics and biological role*
- 25. The role of thermodynamics in solving biomedical problems*
- 26. The method of colorimetry.*
- 27. Entropy of the biosystem*
- 28. The destruction of energy in nature*

*The abstract is performed in accordance with the requirements, within the period specified by the teacher.*

***Work structure:***

*The title page of the abstract should have the following content: the name of the university; name of the faculty; name of department;*

*The title page is the first page on which the ministry is indicated; the name of the educational institution where the work is performed; name of faculty (department); name of specialty, name of educational-professional program, name of academic discipline; topic of the abstract; surname and name of the student, course, number of the academic group, year.*

*The title page is followed by a detailed plan (content) of the abstract, which should highlight the introduction, sections of the main content (main topics studied), their subdivisions (if necessary), conclusion, list of sources used. The table of contents on the right indicates the page numbers at the beginning of each question. Each section begins on a new page.*

*Contents* - a page of work, which contains the title and page numbers of all sections, subsections and paragraphs; the headings of the table of contents must exactly repeat the headings in the text and are placed one below the other (list of symbols if necessary).

**Introduction** - substantiates the relevance of the topic, its practical significance; the object, subject, purpose and tasks of research are defined; the methods by which it was carried out are considered; reveals the structure of the work, its main content. The review should be systematized by the analysis of theoretical, methodical and practical novelty, significance, advantages and disadvantages of works.

Sections and subsections of the main part - the analyzed and systematized material is presented in accordance with the content in the form of separate sections and subsections (chapters and paragraphs); each section covers an independent issue, and the subsection a separate part of this issue; the main idea, and also theses of each division is noted; the theory of the question and the experience of practical work are revealed.

**Conclusions** - the result of the work, presented in the form of separate concise provisions that meet the objectives; there are not only positives and shortcomings, but also specific recommendations for their elimination;

List of used literature (5-10) - reflects the amount of sources used and the degree of study of the research topic; contains a bibliographic description of the sources used by the student while working on the topic.

**Appendices** - are not a mandatory element and are not included in the main limit of the amount of work, but increase the level of confidence in the results of work, indicate their reliability; contain supporting material in the form of samples of questionnaires, tests, tables of supporting digital data, diagrams, graphs, maps, illustrated material, etc.

The total amount of the abstract depending on the chosen topic can vary from 20 to 25 pages of the main text (in agreement with the teacher). The volume of the abstract is determined by the student's ability to briefly and at the same time comprehensively explain and analyze scientific information resources

Mandatory requirement: clear reference to sources of information. All figures, facts, opinions of scientists, quotations, formulas should have a reference in the form of [2] (the number means the number of the source in the bibliography at the end of the creative work. The list of used sources (at least 10 sources) taken from the Internet, you need, as for ordinary literature, specify the author, the title of the article, and then provide the address of the site on the Internet.

The abstract is evaluated by the following criteria: logic of the plan; completeness and depth of disclosure of the topic; correct formulation of conclusions and conclusions; design; substantiation of the student's own opinion on this issue in the form of a conclusion.

Deadline for submission of abstracts for review: 13-14th week of study. Mandatory oral presentation for 3-5 minutes on the chosen topic.

The abstract is not tested for plagiarism, but must meet the requirements of academic integrity. In case of academic dishonesty, the work is canceled and not checked.

## Policy and control

### 7. Attendance policy

#### Attending classes

Attendance at lectures is optional. Attending practical classes is desirable. All works and activities are aimed at the students' compliance with the assessment rating requirements. A significant part of a student rating is formed through active participation in activities in practical classes. Therefore, skipping a practical class does not allow a student to get points in the semester rating. General assessment takes place according to a scheme of the agreed grading system. Expected learning outcomes, control measures and deadlines are announced to students in the first practical class.

#### Control measures missed

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

Skipped express tests/ quizzes cannot be completed.

Skipped Module Test can be worked out in consultations.

#### Violation of deadlines, penalty points and rewarding points

Incentive Points	Criterion	Points
1	Improvement of practical work, active participation in practical classes	1 point (per practical work)
2	Completion of online courses on topics approved by instructors	3 points
3	Writing abstracts on the topics of the course	3 points
4	Preparation of a scientific paper for participation in student research competitions	5 points
5	Participation in international or national events/competitions, or winning a prize in a	10 points

Incentive Points	Criterion	Points
6	university competition related to the course Writing a scientific article on the topics of the course	10 points

*\* if the control measure was missed for a good reason (illness, which is confirmed by a certificate of the established sample) - penalty points are not accrued.*

### **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 "Biothermodynamics and Mass Transfer" can be taught to most students with special educational needs, except for students with severe visual impairments who are not allowed to perform tasks using personal computers, laptops and / or other technical means.*

### **Distance learning**

*Distance learning takes place through the Sikorsky Distance learning Platform «Sikorsky».*

*Distance learning through additional online courses on certain topics is allowed subject to agreement with students. If a small number of students wish to take an online course on a specific topic, studying the material with such courses is allowed, but students must complete all the tasks provided in the discipline.*

*The list of courses is offered by the teacher after the students have expressed a desire (because the bank of available courses is updated almost every month).*

*The student provides a document confirming the completion of the distance course (in the case of a full course) or provides practical tasks from the distance course and subject to an oral interview with the teacher on the topics can receive grades for control measures provided for the studied topics (express control / test tasks, practical work).*

*Performance of practical works is carried out during independent work of students in a remote mode (with a possibility of consultation with the teacher through e-mail, social networks).*

### **Teaching in 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. Monitoring and grading policy**

### **8.1. Grading system (current control):**

№ s/n	Control measure	%	Weight points	Number	Total
1.	Express control works	45	15	3	45
2.	Active work on a practical classes	15	3	5	15

3.	Module Test (MT)	25	25	1	25
4.	Abstract	15	15	1	15
5.	Final Test <sup>1</sup>	85	85	1	85
	Total				100

In the final practical class of the course, students will add their rewarding points, if there are any, to the performance score, and /or subtract their penalty points if there are any, from the performance score, and in case it is in total higher than 60 points, they may either get their Pass or take the Final Test to improve their grade. If the grade for the Final Test is higher than the final performance grade, the student receives the grade based on the results of this Test. If the grade for the Test is lower, the final performance grade is cancelled and the student receives a grade based on the results of the Test.

Students whose final performance grade is 30-60 points have to take the Final Test in order to complete the course.

Students whose score is below 30 did not meet the requirements of the course and are not allowed to take the Final Test.

## 8.2. Work in Practical Classes

**Weighting – 3 points**

**Planned: 5 evaluated answers.**

Grade	Description	Points
Excellent	Complete and correct answers (at least 90% of required information)	3 points
Good	Sufficiently complete answers (at least 75% of required information)	2 points
Satisfactory	Incomplete answers (at least 60% of required information)	1 point
Unsatisfactory	Missing or incorrect answers (less than 60% of required information)	0 points

## 8.3. Modular Test.

**Assessment Criteria for the Modular Test ,**

**Weight of the Modular Test – 25 points**

Grade	Description	Points
Excellent	Complete and correct answers (at least 90% of required information)	20–25 points
Good	Sufficiently complete answers (at least 75% of required information)	14–19 points
Satisfactory	Incomplete answers (at least 60% of required information)	8–13 points
Unsatisfactory	Missing or incorrect answers (less than 60% of required information)	

## 8.4. Research Esse

**Weight – 15 points**

The research paper is assessed according to the following criteria: logical structure of the plan; completeness and depth of topic coverage; accuracy of conclusion formulation; formatting; justification of the student's own opinion on the topic in the form of a conclusion; mastery of the topic (defense of the research paper).

**The defense of the research esse is mandatory.**

**Assessment Criteria for the Research Paper**

Grade	Description	Points
<b>“Excellent”</b>	The research paper is submitted and defended on time; all main requirements are fully met (at least	13–15 points

<sup>1</sup> Taken into account in the amount of the rating together with the grade for CGW in case the student has not scored 60 points per semester or he wants to improve his grade.

Grade	Description	Points
	90%); the student is well oriented in the topic.	
<b>“Good”</b>	the main requirements for the research paper are met with some comments (at least 75%); the student demonstrates a good understanding of the topic. Or: the research paper is submitted after the deadline; the main requirements for the research paper are fully met (at least 90%); the student demonstrates a good understanding of the topic.	10–12 points
<b>“Satisfactory”</b>	Not all main requirements are met (at least 60%); the student is generally oriented in the topic.	7–9 points
<b>“Unsatisfactory”</b>	Main requirements are not met, or the student is not oriented in the topic.	0-6 points

**9. Calendar control (CC)** is performed twice a semester as monitoring of the current state of compliance with syllabus requirements.

The purpose of calendar control is to improve the quality of student learning and monitor the implementation of the schedule of the educational process by students.

Criterion			The first CC	The second CC
Deadline of calendar controls			8th week	14th week
Conditions for obtaining a positive calendar control	Current grade		$\geq 15$ балів	$\geq 25$ балів
	Execution of practical work	KП №№ 1-4	+	+
		KП №№ 5-8	-	+
	Express control works /quizzes	At least 5 of any lectures	+	-
		At least 9 of any lectures	-	+
	Module Test	Estimated MCW	-	+
Abstract				+

In the case of a plagiarism or an academic poor quality during training the control measure is not credited.

#### 10. Semester certification of students

Mandatory requirements for the admission to the Final Test		Criterion
1	Current grade	$RD \geq 35$
2	All practical works are completed	More than 5 points
	Obtaining a positive assessment for the esse	More than 7 points
3	Writing at least 2 control test	More than 15 points

##### 10.1. Assessment Criteria for Final Theoretical Questions (5 questions)

Grade	Description	Score Range
Excellent	The answer is correct and complete (at least 90% of the required information)	75–85 points
Very Good	Minor inaccuracies in the answer (at least 80% of the required information)	65–74 points
Good	Minor inaccuracies in the answer (at least 80% of the required information)	55–64 points
Satisfactory	The answer contains shortcomings and certain errors (at least 60% of the required information)	45–54 points
Sufficient	The answer contains shortcomings and certain errors (at least 60% of the required information)	35–44 points
Unsatisfactory	The answer is absent or does not meet the requirements for a “Satisfactory” grade	0-34 points

##### 10.2. Assessment Criteria for a Final Theoretical Question (Weighting factor – 17)

Grade	Description	Score Range
Excellent	Answers are complete and correct (at least 90% of the required information)	15–17 points
Good	Answers are sufficiently complete (at least 75% of the required information)	12–14 points

Grade	Description	Score Range
<i>Very Good</i>	Minor inaccuracies in the answer (at least 80% of the required information)	9–11 points
<i>Satisfactory</i>	The answer contains shortcomings and certain errors (at least 60% of the required information)	6–8 points
<i>Sufficient</i>	Incomplete answers (at least 60% of the required information)	3–5 points
<i>Unsatisfactory</i>	Answers are absent or incorrect (less than 60% of the required information)	0-3 points

*The results are announced to each student individually, either in person or remotely (by e-mail). The results are also recorded in the “Electronic Campus” system.*

*Optional conditions for admission to the examination:*

- 1. Active participation in practical classes.*
- 2. Positive results of the first and second assessments.*
- 3. Attendance of lecture classes.*

**10.3. The final performance score or the results of the Final Test are adopted by university grading system as follows:**

Number points	Assessment on the university scale
100-95	Excellent
94-85	Very good
84-75	Good
74-65	Satisfactory
64-60	Sufficient Enough
Less 60	Unsatisfactory
The course requirements are not met	Not allowed

#### **11. Additional information on the course (educational component)**

*The list of questions for preparation for modular control work, and also for preparation for credit is given in appendix 1.*

*Distance learning through additional online courses on certain topics is allowed subject to agreement with students. If a small number of students wish to take an online course on a specific topic, studying the material with such courses is allowed, but students must complete all the tasks provided in the discipline.*

*The list of courses is offered by the teacher after the students have expressed a desire (because the bank of available courses is updated almost every month).*

*The student provides a document confirming the completion of the distance course (in the case of a full course) or provides practical tasks from the distance course and subject to an oral interview with the teacher on the topics can receive grades for control measures provided for the studied topics (express control / quizzes, practical work).*

**Work program of the course (syllabus):**

**is developed by:**

*Larisa Kalashnikova ;PhD, Associate Professor of BME, PhD in Biological Sciences,*

*Maryna Sychyk, Associate Professor, Department of BMI PhD (Engineering)*

**Approved by the Department of Biomedical Engineering (Minutes No. 16 dated June 21, 2024)**

**Approved by the Methodical Commission of the Faculty of Biomedical Engineering (Minutes No. 9 dated June 26, 2024)**



***Appendix 1 to the syllabus of the course  
"Biothermodynamics and Mass Transfer"***

***The list of questions for preparation for the Module Test,  
And also for preparation for the Final test***

- 1. Define the concept of system. What other system classifications do you know?*
- 2. What does biothermodynamics study ?. What are the limitations for thermodynamics?*
- 3. What does the thermodynamics of equilibrium and nonequilibrium processes study?*
- 4. What thermodynamic features of the organization of living systems do you know?*
- 5. What are thermodynamic properties? What are the thermodynamic parameters. What types of parameters do you know?*
- 6. What are thermodynamic functions? Describe thermodynamic functions.*
- 7. What is a thermodynamic process? What types of thermodynamic processes do you know?*
- 8. What is a reversible and irreversible process?*
- 9. What thermodynamic states do you know?*
- 10. What is steady state? What are the main characteristics of this condition?*
- 11. Describe the rule of signs?*
- 12. Describe the first law of thermodynamics in application to biological systems*
- 13. What is the enthalpy of the system? Describe Hesse's law.*
- 14. Calorimetry method. Types of method and their characteristics.*
- 15. What is thermal vision. Mechanisms of thermoregulation - a general characteristic.*
- 16. Describe body temperature - internal temperature and shell temperature*
- 17. Mechanisms of heat release.*
- 18. Mechanisms of heat reduction in the body. Internal and external heat flow. What is secondary and primary body heat?*
- 19. What is physical thermoregulation?*
- 20. Mechanisms of body temperature control.*
- 21. Neurohumoral mechanisms of thermogenesis.*
- 22. Factors of thermogenesis.*
- 23. Name the main hemodynamic parameters of blood flow through the vessels. Give them a definition.*

24. *What is the viscosity of a liquid. What is the difference between a Newtonian and a non-Newtonian fluid. Factors that affect blood viscosity.*
25. *What is the entropy of the system. What processes it characterizes. The second law of thermodynamics. Stationary entropy.*
26. *What changes are possible for the entropy of open systems?*
27. *What is a gradient? What types of gradients are characteristic of the biological system?*
28. *Types of blood flow through the vessels: kelp and turbulent. Give a definition. How is the speed calculated?*
29. *Name the basic laws of hemodynamics. What do they demonstrate?*
30. *Name the main driving forces of hemodynamics.*
31. *How to determine the strength of the heart. The main indicator of heart rate. Types of heart work. Which serves as a measure of the work of the heart*
32. *Laps dependence to determine heart pressure.*
33. *What is transmural pressure?*
34. *What parameters of blood determine the peculiarities of its viscosity?*
35. *How to determine the speed of water through the capillary network?*
36. *What is the Reynolds number. What does it show?*
37. *Name the features of the circulatory system as a hemodynamic system.*
38. *Name the properties of erythrocytes that affect hemodynamics of the blood.*
39. *How does the viscosity of blood change depending on the diameter of the vessel?*
40. *What are the main quantitative characteristics of the flow of non-Newtonian fluids?*
41. *Describe the basic law of diffusion. Give a description. What is the diffusion rate*
42. *What is osmosis? Quantitative determination of osmotic flux.*
43. *What is filtering? Quantitative determination of filtration flow.*
44. *Give a comparative description of osmotic, oncotic and filtration pressure.*
45. *How is the glomerular filtration rate determined? What parameters does it depend on?*
46. *Types of air flow in the airways (airways)*
47. *Types of airway resistance - to define and method of their calculation?*
48. *What are the main hemodynamic indicators of blood flow through the vessels? Give them a definition.*
49. *What is hydrodynamic resistance in vessels? How is it determined?*
50. *What is the viscosity of a liquid? What is the difference between a Newtonian and a non-Newtonian fluid?*
51. *Name the factors that affect blood viscosity.*
52. *What is the entropy of the system? What processes does it characterize?*
53. *Describe the second law of thermodynamics.*
54. *What changes are possible for the entropy of open systems?*
55. *Describe the entropy of the steady state.*
56. *What is a gradient? What types of gradients are characteristic of the biological system?*
57. *What is the law of inseparable jet?*
58. *Provide a functional classification of blood vessels.*
59. *Name the main indicators of hemodynamics.*
60. *What is a pulse wave? What indicators are taken into account when calculating the pulse wave velocity?*
61. *Provide a comparative description of blood flow in the arteries and veins*
62. *Describe the blood flow in the capillaries.*

63. *Name the basic laws of hemodynamics. What do they demonstrate?*
64. *What is hemodynamic resistance?*
65. *How is the strength of the heart determined?*
66. *Laps dependence to determine heart pressure?*
67. *What is the main indicator of heart rate?*
68. *Describe the types of heart work.*
69. *How is the power of the heart determined?*
70. *What parameters of blood determine the peculiarities of its viscosity?*
71. *How to determine the speed of water through the capillary network?*
72. *What are the features of the circulatory system as a hemodynamic system?*
73. *Name the properties of erythrocytes that affect blood hemodynamics*
74. *Describe the transport of substances across the membrane*
75. *What is filtering. Quantitative determination of filtration flow*
76. *Types of transcellular transport*
77. *How to determine the glomerular filtration rate. From what parameters of the hall*
78. *Name the driving forces of the filtration process during filtration*
79. *What is osmotic pressure?*
80. *What is oncotic pressure?*
81. *What is filtration pressure?*
82. *Name the active and passive processes in the transfer of gases.*
83. *Describe the work of respiration.*
84. *Types of air flow in the airways (airway)*
85. *What is the diffusion Krog's coefficient ? What determines the resistance to diffusion?*
86. *What is the partial motion of matter, its quantification?*
87. *Name and define pulmonary volumes. What is the volumetric gas flow rate?*
88. *What is the renal filter?*
89. *What are the mechanisms of tubular reabsorption?*