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

Department
biomedical engineering

THERMOBIONICS

Working program of educational discipline (Syllabus)

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

Distribution of hours

Semester	Lectures	Practical	Laboratory	Self-study
spring semester	*22*	*26*		*72*

Curriculum of the discipline

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

*The academic discipline **"Thermobionics"** belongs to the cycle of professional training within the Bachelor's curriculum.*

*The discipline **"Thermobionics"** provides knowledge on the regulation of temperature homeostasis, mechanisms of heat production, and pathways of heat loss in the human body. It offers an understanding of the limits of applicability of the laws of thermodynamics, the classification of thermodynamic parameters, as well as the dimensions and orders of magnitude of the main thermodynamic constants. The course studies active thermal protection of living organisms and possible ways of applying the acquired knowledge in medicine.*

The discipline forms systemic knowledge about the mechanisms of thermoregulation of the organism and the processes responsible for heat release and energy transformation during the interaction of a living organism with the environment.

*The aim of the discipline **"Thermobionics"** is to develop students' ability to establish relationships between various facts and phenomena using methods of biothermodynamics.*

*The discipline **"Thermobionics"** serves as a foundation for understanding the nature of heat as a measure of the motion of matter, as well as the forces underlying the phenomena of heat production and heat transfer.*

*To study the discipline **"Thermobionics"**, the following are required:*

Skills:
– knowledge of the basic methods of thermodynamics;
– skills in determining thermodynamic parameters and characteristic functions;
– understanding of the pathways and conditions of energy transformation during metabolism;
– ability to analyze thermoregulation pathways in living organisms.

Competencies:
– ability to perform calculations of thermodynamic parameters of physicochemical processes when considering their physicochemical nature and the interaction of living systems with the environment;
– ability for abstract thinking, analysis, and synthesis;
– ability to communicate in the state language both orally and in writing;
– skills in 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 " **Thermobionics**." 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 " **Thermobionics**." 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:

Main Sections and Topics to Be Covered During the Course:

Section 1. Basic Characteristics of Biothermodynamics

Topic 1.1. Fundamentals and Basic Principles of the Systems Approach.
Principles, main stages, and methods of systems analysis. Concepts of a system, element, environment, goal, decomposition, function, state, and process.
Topic 1.2. Features of a Living Organism as a Thermodynamic System.
Concepts of work, free energy, and total energy of a system. Internal energy and methods of its change; concepts of work and heat. Fundamental characteristics of life. Energy of life. Functional and network organization and dynamic behavior.
Topic 1.3. Basic Concepts of Thermodynamics.
The concept of a biothermodynamic system and its characteristics. Classification and characterization of systems as a whole. Thermodynamic states of a system. Postulates of biothermodynamics.
Topic 1.4. Thermodynamics of Biological Processes.
The first law of thermodynamics. Enthalpy. Hess's law. Laws of energy conservation. Determination of enthalpy and standard free energy of chemical reactions. Thermal effects of reactions.
The second law of thermodynamics of biological systems. The fundamental thermodynamic equation for biological systems. Statistical interpretation of entropy and the second law of thermodynamics. Entropy as one of the most important thermodynamic functions of biosystems.
Basic thermodynamic potentials. Thermodynamic stability theory; necessary and sufficient conditions for different systems.

Section 2. Fundamentals of Thermoregulation of the Human Body

Topic 2.1. Thermal Balance of the Body.
Regulation of body temperature. Physiological and physical regulation of body temperature. Thermoregulation and its control systems. Thermopathology.
Topic 2.2. Thermoregulation and Its Control Systems.
Features of heat conduction in a living organism. Methods for controlling the thermal balance of the body. Calorimetry of biological and biochemical processes.
Topic 2.3. Temperature Field and Temperature Gradient.
Laws of heat conduction.
Topic 2.4. Thermal Radiation of a Living Organism.
The concept of a black body.
Topic 2.5. Temperature Homeostasis.
The role of feedback mechanisms in energy and mass exchange in biological systems. Determination of driving forces and generalized rates of biological processes from the perspective of energodynamics.

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. Калашнікова, 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/peredmova*
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***
4. ***Biochemical Thermodynamics*** ***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***
10. *Thermodynamics of Biological Systems* ***http://core.ecu.edu/biol/evansc/PutnamEvans/5800PDF/Thermodynamics.pdf***
11. *Ursvon Stockar J. Biothe rmodynamics 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	**Topic 1.1. Fundamentals and Basic Principles of the Systems Approach.** Principles, main stages, and methods of systems analysis. Concepts of a system, element, environment, decomposition, function, state, and process. **Lecture 1.** Fundamentals and basic principles of the systems approach. The concept of a thermodynamic system and the characteristics of thermodynamic systems. **Practical classes:**The discussion is conducted to improve knowledge of general concepts and principles of the structure of complex biological systems, including the human body, its functions from the perspective of the systems approach, and their application in biomedical engineering. Attention is also given to the basic methods and tools used for the quantitative assessment of the functioning of physiological systems.	PLO 18	Practical work 1	1st week
2	**Topic 1.2. Features of a Living Organism as a Thermodynamic System.** Concepts of work, free energy, and total energy of a system. The concept of internal energy and methods of its change; concepts of work and heat. Fundamental characteristics of life. Energy of life. Functional and network organization and dynamism. **Lecture 2.** Basic concepts of thermodynamics. The concept of a biothermodynamic system and its characteristics. Classification and characterization of systems as a whole. Thermodynamic states of a system. Postulates of biothermodynamics. Concepts of work, free energy, and total energy of a system. Internal energy and methods of its change; concepts of work and heat. **Practical classes:**The discussion is conducted to understand the fundamental and applied, medical-physical, and physico-chemical principles governing the functioning of biological objects, as well as the bioengineering foundations of technologies and equipment used to study processes in the human body. The discussion also aims to improve knowledge of general concepts and principles of the structure of complex biological systems, including the human body, its functions from the systems approach perspective, their application in biomedical engineering, and the main methods and tools used for the quantitative evaluation of physiological system functioning.	PLO 18 PLO 22	Practical work 2-3	2nd week
3	**Topic 1.3. Basic Concepts of Thermodynamics.** Thermodynamic states of a system. Postulates of biothermodynamics. **Lecture 3.** The concept of a biothermodynamic system and its characteristics. Classification and characterization of systems as a whole. **Practical classes:** The discussion is conducted to understand the fundamental and applied, medical-physical, and physico-chemical principles governing the functioning of biological objects, as well as the bioengineering foundations of technologies and equipment for studying processes in the human body. It also aims to enhance knowledge of the structure and functioning of complex biological systems, including the	PLO 18 PLO 22	Practical work 3	3rd week

	human body, from the systems approach perspective, and their application in biomedical engineering, as well as quantitative methods for assessing physiological system performance.			
4	**Topic 1.4. Thermodynamics of Biological Processes.** The first law of thermodynamics. Enthalpy. Hess's law. Laws of energy conservation. Determination of enthalpy and standard free energy of chemical reactions. Thermal effects of reactions. **Lecture 4.** The first law of thermodynamics. Thermal effects of reactions. Hess's law and conclusions derived from the fundamental law. **Practical classes:** The discussion is conducted to understand the fundamental and applied, medical-physical, and physico-chemical principles governing the functioning of biological objects, as well as the bioengineering foundations of technologies and equipment used to study processes in the human body. The discussion also aims to improve knowledge of the principles of organization and functioning of complex biological systems, including the human body, from a systems approach perspective, and methods for the quantitative assessment of physiological systems.	*PLO 18* *PLO 22*	*Practical work 4*	*4th week*
5.	**Topic 1.5. The Second Law of Thermodynamics of Biological Systems.** The fundamental thermodynamic equation for biological systems. Statistical interpretation of entropy and the second law of thermodynamics. Entropy as one of the most important thermodynamic functions of biosystems. Basic thermodynamic potentials. Thermodynamic stability theory; necessary and sufficient conditions for different systems. **Lecture 5.**The second law of thermodynamics of biological systems. The fundamental thermodynamic equation for biological systems. Statistical interpretation of entropy and the second law of thermodynamics. **Practical classes:**The discussion is conducted to develop an understanding of fundamental and applied, medical-physical, and physicochemical principles governing the functioning of biological objects, as well as the bioengineering foundations of technologies and equipment used to study processes in the human body. The classes also aim to improve knowledge of general concepts and principles of the structure of complex biological systems, including the human body, 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.	*PLO 18* *PLO 22*	*Practical work 5*	*5th week*
Section 2. Fundamentals of Thermoregulation of the Human Body				
6.	**Topic 2.1. Thermal Balance of the Human Body.** Regulation of body temperature. Physiological and physical regulation of body temperature. Thermoregulation and its control systems. Thermopathology. **Lectures 6–7.**Thermal balance of the body. Methods for determining thermal effects of biological processes. Thermoregulation and its control systems. **Practical classes:**The discussion is conducted to develop an understanding of fundamental and applied, medical-physical, and physicochemical principles governing the functioning of biological objects, as well as the bioengineering foundations of technologies and equipment used to study processes in the human body. The classes also aim to improve knowledge of general concepts and principles of the structure of complex biological systems, including the human body, its functions from a systems approach perspective, and their application in	*PLO 18* *PLO 22* *PLO 18* *PLO 22*	*Practical work 6-7*	*6th -7th week*

	biomedical engineering, as well as the main methods and tools used for the quantitative assessment of physiological system functioning.			
7	**Topic 2.2. Thermoregulation and Its Control Systems.** Features of heat conduction in a living organism. Methods for controlling the thermal balance of the body. Calorimetry of biological and biochemical processes. Temperature homeostasis. The role of feedback mechanisms in energy and mass exchange in biological systems. Determination of driving forces and generalized rates of biological processes from the perspective of energodynamics. **Lecture 8.** Regulation of body temperature. Methods for controlling the thermal balance of the body. Thermometry. Calorimetry. Calorimetry of biological and biochemical processes. Physiological foundations of body temperature regulation. Physical and chemical regulation. The role of the central nervous system in regulation. Types of heat production and heat loss. Physiological and physical regulation of body temperature. Thermopathology. Pathological temperature effects and the body's response to extreme temperature conditions. **Practical classes:**The discussion is conducted to understand fundamental and applied, medical-physical, and physicochemical principles governing biological systems, as well as the bioengineering foundations of technologies and equipment used to study processes in the human body.The classes emphasize the application of bioengineering knowledge for the development and use of artificial biotechnical objects, as well as improving knowledge of systems principles and quantitative assessment methods for physiological system functioning.	*PLO 18* *PLO 22* *PLO 18* *PLO 22*	*Practical work 8*	*8th week*
8.	**Topic 2.3. Temperature Field and Temperature Gradient.** Laws of heat conduction and thermal radiation. Features of heat conduction in living organisms. **Lectures 9–10.**Concepts of temperature field and temperature gradient. Main types of heat transfer in the body. Laws of thermal radiation. **Practical classes:**The discussion is conducted to develop an understanding of fundamental and applied, medical-physical, and physicochemical principles governing biological systems and bioengineering technologies used to study processes in the human body. The classes also aim to improve knowledge of the structure and functioning of complex biological systems from a systems approach perspective and methods for quantitative evaluation of physiological processes.	*PLO 18* *PLO 22* *PLO 18* *PLO 22*	*Practical work 9-10*	*9th -10th week week*
9	**Topic 2.4. Thermal Radiation of a Living Organism.** The concept of a black body. **Lecture 11.**Thermal radiation of the human body. The concept of an absolute black body. Physical methods of heat loss: evaporation, radiation, heat conduction, and convection. **Practical classes:** The discussion is conducted to understand fundamental and applied, medical-physical, and physicochemical principles governing biological systems and bioengineering foundations of technologies and equipment used to study processes in the human body. Practical classes include the application of bioengineering knowledge for the development and use of artificial biotechnical objects, as well as improving knowledge of systems principles and quantitative methods for assessing physiological system functioning.	*PLO 18* *PLO 22* *PLO 18* *PLO 22*	*Practical work 11*	*11th week*
10.	Submission esse		*Practical work 12*	*12th week*
11.	Module test		*Practical work 13*	*13th week*
12	Abstract			*14th – 15th 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* *Principles, main stages, and methods of systems analysis. Concepts of a system, element, environment, function, state, and process.*	1	2	1	2	*Practical work №1*
Topic 1.2. *Peculiarities of a Living Organism as a Thermodynamic System* *Concepts of work, free energy, and total energy of a system. Internal energy and methods of its change, concepts of work and heat. Key characteristics of life. Energy of life. Functional and network organization and dynamism.*	2	2	2	2	*Practical work №2*
Topic 1.3. *Basic Concepts of Thermodynamics* *Concept of a biothermodynamic system and its characteristics. Classification and description of a system as a whole. Thermodynamic states of the system. Postulates of biothermodynamics.*	3	2	3	2	*Practical work №3* Test №1
Тема 1.4 *Thermodynamics of Biological Processes* *The first law of thermodynamics. Enthalpy. Hess's law. Laws of energy conservation. Determination of enthalpy and standard free energy of a chemical reaction. Thermal effect of the reaction.*	4	2	4	2	*Practical work №4*
Тема 1.5. *The Second Law of Thermodynamics in Biological Systems The fundamental thermodynamic equation for biological systems. Main thermodynamic potentials. Thermodynamic theory of stability; necessary and sufficient conditions for different systems..*	5	2	5	2	*Practical work №5*
Section 2. Fundamentals of Human Thermoregulation					
Topic 2.1. *Thermal Balance of the Body Regulation of body temperature. Physiological and physical mechanisms of body temperature regulation. Thermoregulation and its control systems. Thermopathology.*	6-7	4	6	2	*Practical work № 6*
			7	2	*Practical work* *№ 7*
Topic 2.2. *Heat Transfer in the Living Organism Peculiarities of heat conduction in living organisms. Methods for controlling the body's thermal balance. Calorimetry of biological and biochemical processes.*	8	2	8	2	*Practical work* *№ 8* Test 2
Topic 2.3. *Temperature Field and Temperature Gradient Laws of heat conduction. Thermal radiation of living organisms. Concept of a black body.*	9-10	4	9	2	*Practical work №9*
			10	2	*Practical work №10*
Topic 2.4. Temperature Homeostasis *The role of feedback in energy and mass exchange in biological systems. Determination of driving forces and generalized rates of biological processes from the perspective of energodynamics.*	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)**	

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
Total		**72**

Distribution of Student Independent Work Hours by Topic

№ з/п	*Titles of Topics and Questions Assigned for Independent Study and References to Educational Literature*	*Number of Hours of Independent Work (IWS)*
1	*Fundamentals and Basic Principles of the Systems Approach Principles, main stages, and methods of systems analysis. Concepts of a system, element, environment, function, state, and process.* ***List of Questions for Independent Study:*** *Fundamentals and basic principles of the systems approach. Concept of a thermodynamic system, characteristics of a thermodynamic system [1, 2].*	*5*
2	*Peculiarities of a Living Organism as a Thermodynamic System. Concepts of work, free energy, and total energy of a system. Internal energy and methods of its change, concepts of work and heat. Key characteristics of life. Energy of life. Functional and network organization and dynamism.* ***List of Questions for Independent Study:*** *Concept of internal energy and methods of its change; concepts of work and heat. Key characteristics of life. Energy of life. [1, 2].*	*5*
3	*Basic Concepts of Thermodynamics. Concept of a biothermodynamic system and its characteristics. Classification and description of the system as a whole. Thermodynamic states of the system. Postulates of biothermodynamics.* ***List of Questions for Independent Study:****Thermodynamic states of the system. Postulates of biothermodynamics.[1, 2, 5].*	*5*
4	*Thermodynamics of Biological Processes.The first law of thermodynamics. Enthalpy. Hess's law. Laws of energy conservation.* ***List of Questions for Independent Study:****Determination of enthalpy and standard free energy of a chemical reaction. Thermal effect of the reaction.[1, 2, 5].*	*5*
5	*The Second Law of Thermodynamics in Biological Systems The fundamental thermodynamic equation for biological systems. Main thermodynamic potentials.* ***List of Questions for Independent Study:****Thermodynamic theory of stability; necessary and sufficient conditions for different systems.[3].*	*5*
6	*Peculiarities of Heat Transfer in the Living Organism. Methods for controlling the body's thermal balance.* ***List of Questions for Independent Study:****Calorimetry of biological and biochemical processes [3, 6].*	*5*
7	*Temperature Field and Temperature Gradient.Laws of heat conduction.* ***List of Questions for Independent Study:****Thermal radiation of living organisms. Concept of a black body [4, 6].*	*5*
8	*Temperature Homeostasis. The role of feedback in energy and mass exchange in biological systems.* ***List of Questions for Independent Study:****Determination of driving forces and generalized rates of biological processes from the perspective of energodynamics.[3-5].*	*5*
10	**Module Control Work**	*10*
11	**Esse Report**	*12*
12	**Credit**	*10*
	Total	*72*

6.2. Preparation for Classroom Activities

Preparation for classroom activities is carried out according to the course plan, using the references provided on the MOODLE platform, and by completing the control tests available on MOODLE. Students are also encouraged to choose a topic for their research paper and prepare a 5–7 minute presentation.

6.3. Module Control Work (MCW)

Ten hours of independent work (IWS) are allocated for preparation for the Module Control Work.

6.4. Research Paper

One of the main types of semester assessment in the Thermobionics course is the research paper. The research paper must be completed in accordance with the requirements and submitted by the deadline specified by the instructor. The final submission deadline is the 12th week of the semester.

The main purpose of the research paper is to analyze literary sources and independently systematize theoretical material. A student may write a research paper only on a topic approved by the instructor.

A research paper is a type of written work on a specific topic, with information collected from various sources, including less known and current literature on the subject.

The research paper serves as a form of assessment of the student's knowledge on the topics of the course.

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 university competition related to the course	10 points
6	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*[1]	*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)	

[1] *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.*

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
"Excellent"	The research paper is submitted and defended on time; all main requirements are fully met (at least 90%); the student is well oriented in the topic.	13–15 points
"Good":	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
"Satisfactory"	Not all main requirements are met (at least 60%); the student is generally oriented in the topic.	7–9 points
"Unsatisfactory"	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*		*≥ 15 балів*	*≥ 25 балів*
	Execution of practical work	*КП №№1-4*	+	+
		КП №№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 ≥ 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
Very Good	Minor inaccuracies in the answer (at least 80% of the required information)	9–11 points
Satisfactory	The answer contains shortcomings and certain errors (at least 60% of the required information)	6–8 points
Sufficient	Incomplete answers (at least 60% of the required information)	3–5 points
Unsatisfactory	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

*" **Thermobionics”***

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?