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

Department
biomedical engineering

Thermodynamics of biological processes systems

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:*** *PhD Associate Professor of BME, Candidate of Biological Sciences* *Kalashnikova Larysa , e-mail – doc_hom2000@yahoo/com* ***Practical:*** *PhD Associate Professor of BME, Candidate of Biological Sciences* *Kalashnikova Larysa , e-mail – doc_hom2000@yahoo/com*
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	*28*	*44*		*48*

Curriculum of the discipline

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

*Course **"Thermodynamics of biological processes and systems"** 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 **Thermodynamics of biological processes and systems"** forms in students the ability to establish a connection between various facts and phenomena and using the methods of biothermodynamics.*

*The Course **"Thermodynamics of biological processes and systems"** 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 ***"Thermodynamics of biological processes and systems"*** *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 *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

GC 1 - *Ability to apply knowledge in practical situations.*

GC 2 - *Knowledge and understanding of the subject area and understanding of professional activity.*

GC 3 *- Ability to communicate in the state language both orally and in writing.*

GC 6 - *Ability to search, process and analyze information from various sources.*

GC 7 *- Ability to generate new ideas (creativity).*

GC 8 *- Ability to make well-grounded decisions.*

Special (professional) competencies *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

PC 3 *- Ability to study and apply new methods and tools for analysis, modeling, design and optimization of medical devices and systems.*

PC 4 *- Ability to provide technical and functional characteristics of systems and tools used in medicine and biology (in prevention, diagnosis, treatment and rehabilitation).*

PC 5 *- Ability to apply physical, chemical, biological and mathematical methods in the analysis, modeling of the functioning of living organisms and biotechnical systems.*

PC 11 *- Ability to understand the technical and functional characteristics of systems, methods and procedures used in prevention, diagnosis and therapy.*

PC 12 *- Ability to develop, plan and apply mathematical methods in the analysis, modeling of the functioning of living organisms, systems and processes in biology and medicine.*

The program learning outcomes after studying the discipline "Thermodynamics of biological processes and systems" are *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

PLO 1 *- Understanding of fundamental-applied, medical-physical and bioengineering bases of technologies and equipment for research of processes of a human body*

PLO 5 *- Knowledge of research methods and techniques used in the design of medical equipment .*

PLO 6 *- Knowledge of object research methods, analysis and processing of experimental data.*

PLO 7 *- Understanding of scientific and technical principles that underlie the latest advances in biomedical engineering.*

PLO 8 *- Knowledge of a foreign language to the extent sufficient for general and professional communication .*

PLO 10 *- Knowledge of the basic physical and physicochemical patterns of biological objects functioning.*

PLO 11 - *Knowledge of the basic conditions of operation of diagnostic and therapeutic systems, medical complexes and systems.*

PLO 17 - *Knowledge of general information about the human body and its functions from the* ***standpoint*** *of a systems approach and their use in biomedical engineering .*

PLO 23 - *Knowledge of universal principles of complex biological systems structure, including the human body .*

PLO 24 - *Apply knowledge of the basics of mathematics, physics and biophysics, bioengineering, chemistry, engineering graphics, mechanics, resistance and strength of materials, properties of gases and liquids, electronics, computer science, obtaining and analyzing signals and images, automatic control, systems analysis and decision making methods at the level required to solve the problems of biomedical engineering.*

PLO 43 - The use of methods and means of quantitative evaluation of the functioning of physiological systems in practical engineering..

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

The discipline ***"Thermodynamics of biological processes and systems"*** *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 ***"Thermodynamics of biological processes and systems"*** *is closely related to other disciplines of professional training: 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 a systems approach. The concept of system. Classification and characterization of the system as a whole. Features of a living oganim as a thermodynamic system. Postulates of biothermodynamics

Topic 1.2. Thermodynamics of biological processes. Laws of energy conservation. The concept of operation, free and total energy of the system. Thermodynamics of biological processes. Determination of enthalpy and standard free energy of a chemical reaction

Topic 1.3. The main types of heat transfer in the body. Temperature field and temperature gradient Thermoregulation and its control systems

Topic 1.4. Thermal balance of the body. Body temperature regulation

Topic 1.5. The second law of thermodynamics. Clausius' theorems, entropy, 2nd and 3rd formulations of the second law of thermodynamics. Thermodynamic theory of stability, necessary and sufficient conditions for different systems.

Topic 1.6. Non-equilibrium thermodynamics: local equilibrium hypothesis, transfer theorem and entropy balance equation, entropy production.

Topic 1.7. Thermodynamic potentials and their biological significance

Sectionl 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 gate connections in energy mass transfer

4. Coursebooks and teaching resources

Basic:

1. *Anaesth Br. J.. THERMODYNAMICS OF BIOLOGICAL PROCESSES J. G. MORRIS, 1974.-210 p.* ***https://pdf.sciencedirectassets.com/318044/1-s2.0-S0007091217X66634/1-s2.0-S0007091217496322/main.pdf?X-Amz-Security-Token.***
2. *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***
3. *Kukurová Elena.Basics of Medical Physics and Biophysics for electronic education of health professionals Asklepios, Bratislava 2013.-214 p.* ***https://zona.fmed.uniba.sk/uploads/media/Basics_of_Biophysics.pdf***
4. *Gautham Vasantha Pattabhi N. Biophysics, Narosa Publishing House DELHI CHENNAI MUMBAI KOLKATA , 2005.- 247 p.* ***https://www.ewingdigital.com/text_content/115875395635e9fee6bc8286.pdf***
5. *Kaksis Aris BioThermodynamics Riga University, 2021.* ***http://aris.gusc.lv/BioThermodynamics/BioThermodynamics.pdf***
6. *Cramer W. A. , Soriano G. M. Thermodynamics of Energy Transduction in Biological Membranes Bloomfield,* ***Biophysics*** *Textbook On-Line ; Eisenberg, 2002.-58 p.* ***https://www.biophysics.org/Portals/0/BPSAssets/Articles/cramer.pdf***
7. *Urbanc Brigita Biophysics Lecture Notes, 2012.* ***http://www.physics.drexel.edu/~brigita/COURSES/BIOPHYS_2011-2012/***
8. *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***
9. Антонюк В. С., *Біофізика* і біомеханіка [Електронний ресурс] : *підручник* /. В. С. Антонюк, М О. Бондаренко, В. А. Ващенко та ін. ; НТУУ «КПІ». 2012 – 344 с **https://ela.kpi.ua/bitstream/123456789/18652/1/Антоноюк-биофизика. pdf**
10. Антонов В.Ф., Черныш А.М., Пасечник В.И., Вознесенский С.А., Козлова Е.К. Биофизика: Учеб. для студ. высш. учеб. заведений. — М.: Гуманит. изд. центр ВЛАДОС, 1999. — 288 с. ***http://www.chelsma.ru/files/misc/antonovv.f.-biofizika.2000.pdf***
11. Ершов, Ю. А.Биотехнические системы медицинского назначения. В 2 ч. Часть 1. Количе-ственное описание биообъектов : учебник для бакалавриата и магистратуры / Ю. А. Ершов, С. И. Щукин. — 2-е изд. испр. и доп. — М. : Издательство Юрайт, 2018. — 181 с. ***https://docplayer.com/143551045-Biotehnicheskie-sistemy-medicinskogo-naznacheniya-chast-1-kolichestvennoe-opisanie-bioobektov.html***

12. Гарбузова В.Ю. Опорний конспект лекції з фізіології на тему ©.:Основи гемодинаміки/ СУМСЬКИЙ ДЕРЖАВНИЙ УНІВЕРСИТЕТ МЕДИЧНИЙ ІНСТИТУТ КАФЕДРА ФІЗІОЛОГІЇ І ПАТОФІЗІОЛОГІЇ 2018.-556 с.
https://essuir.sumdu.edu.ua/bitstream-download/123456789/39240/1/ Hemodynamics Garbuzova.pdf
13. Корнющенко Г. С. Медична та біологічна фізика: практикум : навчальний посібник : у 2 ч. / Г. С. Корнющенко, У. С. Швець, Л. Ф. Суходуб. – Суми : Сумський державний університет, 2017. – Ч. 1. – 186 с
https://essuir.sumdu.edu.ua/bitstream-download/123456789/65176/1/ Korniushchenko_ medychna .pdf
14. Огурцов А.Н. Фиико-химические основі биотехнологий. Биотермодинамика. Учеб. Пособие; Харьков, НТУ «ХПИ», 211.- 256 с
http://repository.kpi.kharkov.ua/bitstream/KhPI-Press/22/1/Biotermodinamika_Ogurtsov-2011.pdf
15. Сливко Е.І., Мельнікова О.З., Іванченко О.З.,. Біляк Н.С МЕДИЧНА І БІОЛОГІЧНА ФІЗИКА: Навчальний посібник для студентів спеціальності 222 «Медицина»/. - Запоріжжя, 2018.- 291 с.
http://dspace.zsmu.edu.ua/bitstream/123456789/7798/4/ Медична% 20і%20біологічна %20 фізика .pdf
16. Трухан Э.М. Т77 Введение в биофизику: Учебное пособие. – М.: МФТИ, 2008.
https://mipt.ru/dbmp/upload/97e/biophys_trukhan-arphlf43r09.pdf
17. Чалий О.В. Медична та біологічна фізика : Підручник для ВМНЗ III-IV р.а. [текст] 2015.- 384 с
https://studfile.net/preview/1902522/

Supplementary:

1. *Biochemical Thermodynamics*
https://www.chem.uwec.edu/chem406_f06/pages/lecture_notes/lect03/Atkins-Ch1.pdf
2. *Dadan Rosana Biophysics: An Introduction, 2012. - 38 p.*
http://staffnew.uny.ac.id/upload/132058092/pendidikan/biophysics-book.pdf
3. *Dillon Patrick F. Biophysics A Physiological Approach, 2016.- 314p*
https://epdflibrary.com/map2/1107001447
4. *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
5. *ENGINEERING THERMODYNAMICS [For Engineering Students of All Indian Universities and Competitive Examinations] By R.K. RAJPUT M.E. (Heat Power Engg.) Hons.–Gold Medallist ; Grad. (Mech. Engg. & Elect. Engg.) ; M.I.E. (India) ; M.S.E.S.I. ; M.I.S.T.E. ; C.E. (India) Principal (Formerly) Punjab College of Information Technology PATIALA, Punjab 2007.- 966 p*
https://uowa.edu.iq/filestorage/file_1551541671.pdf
6. *Kappen Bert Introduction to biophysics, Department of Biophysics Radboud University Nijmegen February 7, 2008*
http://www.snn.ru.nl/~bertk/biofysica/handouts.pdf
7. 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
8. *Thermodynamics of Biological Systems*
http://core.ecu.edu/biol/evansc/PutnamEvans/5800PDF/Thermodynamics.pdf

9. *Biochemical Thermodynamics*
https://www.chem.uwec.edu/chem406_f06/pages/lecture_notes/lect03/Atkins-Ch1.pdf
10. *Dadan Rosana Biophysics: An Introduction, 2012. - 38 p.*
http://staffnew.uny.ac.id/upload/132058092/pendidikan/biophysics-book.pdf
11. *Dillon Patrick F. Biophysics A Physiological Approach, 2016.- 314p*
https://epdflibrary.com/map2/1107001447
12. *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
13. *ENGINEERING THERMODYNAMICS [For Engineering Students of All Indian Universities and Competitive Examinations] By R.K. RAJPUT M.E. (Heat Power Engg.) Hons.–Gold Medallist ; Grad. (Mech. Engg. & Elect. Engg.) ; M.I.E. (India) ; M.S.E.S.I. ; M.I.S.T.E. ; C.E. (India) Principal (Formerly) Punjab College of Information Technology PATIALA, Punjab 2007.- 966 p*
https://uowa.edu.iq/filestorage/file_1551541671.pdf
14. *Kappen Bert Introduction to biophysics, Department of Biophysics Radboud University Nijmegen February 7, 2008*
http://www.snn.ru.nl/~bertk/biofysica/handouts.pdf
15. 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

Educational content

5. Methods of mastering the discipline (educational component)

№ s/n	*Subject*	*Program learning outcomes*	*The main tasks*	
			Control measure	*Термін виконання*
1	Fundamentals and basic principles of a systems approach. The concept of thermodynamic system, characteristics of thermodynamic system.	*PLO 1* *PLO 5* *PLO 6* *PLO 7*	*Practical work 1*	*1st week*
2	The main signs of life. Energy of life. Functional and network structure and dynamism	*PLO 8.* *PLO 10* *PLO 17* *PLO 23*	*Practical work 2-3*	*2nd week*
3	Basic concepts of thermodynamics. The concept of biothermodynamic system and its characteristics Classification and characteristics of the system as a whole. Thermodynamic states of the system. Postulates of biothermodynamics	*PLO 8.* *PLO 10* *PLO 17* *PLO 23*	*Practical work 4*	*3rd week*
4	Features of a living organism as a thermodynamic system The concept of	*PLO 1* *PLO 6* *PLO 8*	*Practical work 5-6*	*4th week*

	work, free and total energy system The concept of internal energy ways to change its concept, work and heat.	*PLO 10* *PLO 17*		
5.	The main types of heat transfer in the body. Temperature field and temperature gradient Thermoregulation and its control systems	*PLO 1* *PLO 23* *PLO 24* *PLO 43*	*Practical work 7*	*5th week*
6.	Thermal balance of the body. Body temperature regulation.	*PLO 6* *PLO 23* *PLO 24* *PLO 43*	*Practical work 8-9*	*6th week*
7	Methods of control of thermal balance of an organism. Calorimetry of biological and biochemical processes	*PLO 1* *PLO 17* *PLO 24* *PLO 43*	*Practical work 10*	*7th week*
8.	The second law of thermodynamics Clausius' theorems, 2nd and 3rd formulations of the second law of thermodynamics. The concept of entropy. Thermodynamic theory of stability, necessary and sufficient conditions for different systems. Theory of energy dissipation	*PLO 8* *PLO 10* *PLO 17* *PLO 23*	*Practical work 11-12*	*8th week*
9	Thermodynamic potentials and their biological significance Influence of entropy and enthalpy factors on the possibility of spontaneous process.	*PLO 8* *PLO 10* *PLO 17* *PLO 23* *PLO 43*	*Practical work 13*	*9th week*
10.	Transfer theorem and entropy balance equation, entropy production. Prigogine's theorem. Conjugacy of flows. The principle of symmetry of Onsager kinetic coefficients. state of open systems and Prigogine's theorem on the minimum entropy production Open medico-biological systems that are far from equilibrium (elements of synergetics. The organism as an open thermodynamic system. Prigogine's theorem. Steady state and velocity of entropy production. Dissipative function of entropy	*PLO 8* *PLO 10* *PLO 17* *PLO 23*	*Practical work 14*	*10th week*
11.	The cell as an open system. Metabolism. Plastic (assimilation) and energy (dissimilation) exchange. Energy sources for organisms. Autotrophic and	*PLO 1* *PLO 8* *PLO 10* *PLO 17*	*Practical work 15*	*11th week*

	heterotrophic organisms. Stages of energy conversion in the body: preparatory, anaerobic (oxygen-free) and aerobic (oxygen). Aerobic and anaerobic respiration. Features of energy metabolism in living organisms as open systems. Macroergic compounds .. Energy conjugations in living systems: exergonic and endergonic processes in the body	*PLO 23*		
12	Dynamic properties of biological processes. Types of dynamic behavior of biological systems	*PLO 1* *PLO 8* *PLO 10* *PLO 17*	*Practical work 16-17*	*12th week*
13	Transfer phenomena at the border. Fundamentals of diffusion in a living organism. Membrane mass transfer Flow density. The average free path length of the molecule. Diffusion. Fick's equation. Viscosity. Newton's equation. Fourier equation. . Energy migration and electron transfer in biostructures. Physico-chemical features of biological membranes. Mechanisms of sorption and desorption	*PLO 5* *PLO 8* *PLO 11* *PLO 43*	*Practical work 18*	*13th week*
14	Thermodynamics of the mechanism of muscle contraction	*PLO 1* *PLO 8* *PLO 10* *PLO 17* *PLO 23*	*Practical work 19*	*14th – 15th week*
15	The value of feedback in energy mass transfer in the biological system. Finding the driving forces and generalized velocities of biological processes from the standpoint of energy dynamics	*PLO 10* *PLO 17* *PLO 23* *PLO 24* *PLO 43*		
16	*Значення звортних зв'язки у енерго масообміну у біологічній системі* Знаходження рушійних сил і узагальнених швидкостей біологічних процесів з позицій енергодінамікі	*PLO 6* *PLO 17* *PLO 23* *PLO 24*	*Practical work 20* Module test	*16th week*
17	Abstract		*Practical work 21*	*17th week*
18	Final tests		*Practical work 22* Final tests pass	*18th week*

6. Self-study

One of the main types of semester control during the mastering of the discipline ***"Thermodynamics of***

biological processes and systems" *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. The first law of thermodynamics in biosystems.
4. The second law of thermodynamics in relation to the biosystem.
5. The concept of enthalpy. Hesse's thermal law.
6. Thermodynamic potentials - their characteristics and biological essence.
7. Entropy of the biosystem.
8. Destruction of energy in nature
9. Thermodynamics of open (biological) systems
10. Thermodynamic characteristics of transport of substances across the membrane
11. Features of filtration
12. Flows and their interaction near thermodynamic equilibrium. Onsager reciprocity ratio.
13. Biological significance of the combination of flows in a thermodynamic system. Condition of combination of flows. Coupling factor
14. Dissipative function of energy.
15. The concept of information. Quantitative evaluation of information. The meaning of information.
16. Information and questions about the orderliness of biological objects.
17. Macro and micro information. The value of information. Trigger.

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

Rewarding points		*Penalty points**	
Criterion	*Weight points*	*Criterion*	*Weight points*
Active classroom work in the form of three additional answers to the question.	*1 point (for each reasonable additional answer)*	*Uncorrect of Home work*	*From -0.5 points to -5 points (depending on the delivery date)*
Independent in-depth theoretical training on the topic of practical training	*3 points*	*Untimely implementation of a Home Test*	*- From -2 points to -20 points (depending on the delivery date*

** 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 ***"Thermodynamics of biological processes and systems"*** *" 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

Grading system (current control):

№ s/n	Control measure	%	Weight points	Number	Total
1.	Express control works	15	3	5	15
2.	Active work on a practical classes	30	5	6	30
3.	Module Test (MT)	25	25	1	25
4.	Abstract	30	30	1	30
5.	Final Test[1]	70	70	1	70
	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.

***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		≥ 24 балів	≥ 40 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

[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.*

credited.

Semester certification of students

	Mandatory requirements for the admission to the Final Test	*Criterion*
1	*Current grade*	*RD ≥ 40*
2	*All practical works are completed*	*More than 0 points*
	Obtaining a positive assessment for the performed Home Test	*More than 15 points*
	Obtaining a positive assessment for the performed Module Test	*More than 10 points*
3	*Writing at least 3 express control works*	*More than 6 points*

The results are announced to each student separately in the presence or remotely (by e-mail). It is also recorded in the "Electronic Campus" system.

Optional requirements for admission to closure:

1. *Active work during practical classes.*
2. *Positive result of the first and the second calendar control.*
3. *Attending of lectures.*

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 / Відмінно*
94-85	*Very good / Дуже добре*
84-75	*Good / Добре*
74-65	*Satisfactory / Задовільно*
64-60	*Sufficient Enough / Достатньо*
Less 60	*Unsatisfactory / Незадовільно*
The course requirements are not met	*Not allowed / Не допущено*

9. 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** PhD, Associate Professor of BME, Candidate of Biological Sciences, Larisa Kalashnikova*

***Approved by** the Department of Biomedical Engineering (protocol № ___ to _____)*

***Approved by** the Methodical Commission of the Faculty of Biomedical Engineering (protocol № __ to _____)*

Appendix 1 to the syllabus of the course

"Thermodynamics of biological processes and systems"

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 hall78. Name the driving forces of the filtration process during filtration

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 coefficient of Krog? 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?