



Quantitative Physiology

Syllabus of the academic discipline (Syllabus)

Requisites for basic discipline

Level of higher education	First (bachelor's)
Field of study	16 Chemical Engineering and Bioengineering
Speciality	163 Biomedical Engineering
Educational program	Medical Engineering
Course status	Required (standard) discipline
Mode of study	full-time / day / mixed / remote
Year of study, semester	2nd year of study, autumn semester
Course workload	5 ECTS credits / 150 hours
Semester control / Control measures	Final test, Module test
Course schedule	According to the schedule on the site http://rozklad.kpi.ua/
Language of instruction	English
Information about course leader / teachers	<p>Lecturer: Ph.D. in Biology, Associate Professor of the Department of Biomedical Engineering, Svitlana Vovianko, e-mail – s.vovianko-fbmi@lil.kpi.ua, Senior lecturer Gann Ovcharenko, e-mail – ovcharenko.ganna@lil.kpi.ua</p> <p>Practical: Ph.D. in Biology, Associate Professor, Department of Biomedical Engineering, Svitlana Vovianko, e-mail – s.vovianko-fbmi@lil.kpi.ua, Senior lecturer Ganna Ovcharenko, e-mail – ovcharenko.ganna@lil.kpi.ua</p> <p>Laboratory: Ph.D. in Biology, Associate Professor, Department of Biomedical Engineering, Svitlana Vovianko, e-mail – s.vovianko-fbmi@lil.kpi.ua, Senior lecturer Ganna Ovcharenko, e-mail – ovcharenko.ganna@lil.kpi.ua</p>
Course placement	Platform "Sikorsky" - https://do.ipk.kpi.ua:course "Quantitative Physiology" (hd79vz)

Distribution of hours

Semester	Lectures	Practical	Laboratory	Self-study
autumn semester	36	36	18	60

Curriculum of the discipline

1. Course Description, Aim, Subject Matter and Learning Outcomes

The academic discipline "Quantitative Physiology" plays a significant role in the training of bachelors in the specialty 163 "Biomedical Engineering." Studying this discipline contributes to the development of natural-science thinking and the ability to use methods and tools of quantitative assessment and analysis of the functioning of physiological systems in practical engineering activities.

The discipline examines basic physiological principles from the perspective of their quantitative aspects. Within the course, the main emphasis is placed on understanding the relationships between

physiological parameters, knowledge of their ranges, and the ability to calculate flows or forces within the body, which is a necessary foundation for the development of biotechnical devices for supporting or replacing vital body functions.

The aim of the discipline is to form students' competencies in accordance with the educational and professional program "Medical Engineering."

Integral competence (EP was put into effect by the Rector's Order NON/434/2024 of June 10, 2024):

IC - The ability to solve complex, specialized problems and practical problems in biomedical engineering and in the process, which provides the use of specific theories and methods of chemical, biological and medical engineering, and is characterized by the complexity and non-strict terms

General competencies (EP was put into effect by the Rector's Order NON/434/2024 of June 10, 2024):

3K 02 – Knowledge and understanding of the subject area and understanding of professional activities.

3K 05 – Ability to conduct research at an appropriate level.

3K 06 – Ability to search, process, and analyse information from various sources.

Professional competencies (EP was put into effect by the Rector's Order NON/434/2024 of June 10, 2024):

ΦK 11 – Ability to develop, plan, and conduct experiments using specified technical and biomedical techniques, applying mathematical methods in the analysis and modeling of the functioning of living organisms, systems, and processes in biology and medicine, computer processing, analysis, and synthesis of the obtained results.

Programme learning outcomes after completing the course "Quantitative Physiology" include (EP was put into effect by the Rector's Order NON/434/2024 of June 10, 2024):

PPH 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.

PPH 21 – Understanding and use of scientific and technical principles, methods, and research tools for the development, planning, and design of experimental and new researches in the field of biomedical engineering using medical, biological, biomedical devices and biotechnical systems, medical biomaterials, as well as for quantitative assessment of the functioning of physiological systems.

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

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

The academic discipline "Quantitative Physiology" belongs to the cycle of professional training

Prerequisites: the course is taught in the 1st semester of the 2nd year of study and is directly preceded by the disciplines "Human Anatomy and Physiology" та "Biochemistry".

Postrequisites: according to the structural and logical scheme of the specialist training program, the discipline "Quantitative Physiology" is closely related to other professional training courses. The

theoretical knowledge and practical skills acquired during the study of the academic discipline “Quantitative Physiology” are applied in mastering the course “Methods of Modeling and Analysis of Biomedical Processes and Systems,” as well as in the study of elective courses such as “Laboratory and Analytical Techniques”, “Methods and Tools for the Diagnosis of Human Pathology”, and “Therapeutic Medical Equipment”

3. The content of the discipline

Main sections and topics to be covered during the course:

Section 1. Systemic Approach in Physiology

Topic 1.1. Application of systemic approach principles in the study and modeling of interactions between biological and engineering–technical systems.

Section 2. Quantitative Characteristics of Electromagnetic Processes in the Body

Topic 2.1. Fundamental-applied, medical-physical, and physico-chemical principles governing the functioning of biological objects. Origin of bioelectrical signals. The role of bioelectrogenesis in excitation. Methods for studying bioelectrogenesis.

Topic 2.2. Propagation of excitation in nerve and muscle fibers. Electrical synaptic transmission and chemical synapses.

Topic 2.3. Quantitative electrophysiology of the brain. Instrumental methods for studying the bioelectrical activity of the cerebral cortex.

Topic 2.4. Quantitative electrophysiology of the heart. Generation of biopotentials and the cardiac conduction system. Formation of the ECG signal.

Section 3. Quantitative Characteristics of Mass Transfer in the Human Body

Topic 3.1. The circulatory system: medical and physical principles of functioning, research methods, and instrumental tools for quantitative assessment of function.

Topic 3.2. The respiratory system: medical and physical principles of functioning, technologies and equipment for research, methods and tools for quantitative assessment of function.

Topic 3.3. The water–electrolyte homeostasis system. Application of artificial biological and biotechnical objects and medical materials in systems for supporting and replacing excretory functions.

4. Training materials and resources

Basic literature:

1. *Quantitative Physiology. Laboratory workshop [Electronic resource] : workshop on discipline for students of specialties 163 "Biomedical Engineering", the educational programs "Medical Engineering" / Igor Sikorsky Kyiv Polytechnic Institute ; compilers: S. I. Vovianko. G. R. Ovcharenko. – Electronic text data (1 file: 3,13 MB). – Kyiv : Igor Sikorsky Kyiv Polytechnic Institute, 2021 – 51 p. // <https://ela.kpi.ua/handle/123456789/45160>*
2. *Кількісна фізіологія: Лабораторний практикум [Електронний ресурс]: навч. посіб. для студентів спеціальності 163 «Біомедична інженерія», освітньо-професійна програма підготовки «Медична інженерія» / КПІ ім. Ігоря Сікорського ; уклад.: С.І. Вовянко, Г.Р. Овчаренко, С.В. Зубков. – КПІ ім. Ігоря Сікорського. – Електронні текстові дані (1 файл: 3,3 Мбайт). – Київ: КПІ ім. Ігоря Сікорського, 2021. – 131 с. // <https://ela.kpi.ua/handle/123456789/45159>*
3. *Кількісна фізіологія. Завдання до виконання домашньої контрольної роботи: навчальні матеріали для самостійного та дистанційного вивчення для здобувачів ступеня «бакалавр» за освітньою програмою «Медична інженерія» спеціальності 163*

«Біомедична інженерія» / КПІ ім. Ігоря Сікорського ; уклад.: С.І. Вовянко, Г.Р. Овчаренко. – КПІ ім. Ігоря Сікорського, 2021. – 24 с. // <https://do.ipu.kpi.ua/course/view.php?id=3255>

4. Пасічніченко О.М., Макарчук М.Ю. фізіологія нервів і м'язів (Навчальний посібник). – Київ, 2020. – 157с.
5. Філіппов, В. І. Фізіологія людини : підручник для студентів медичних закладів фахової передвищої та вищої освіти / М.М. Філіппов. – Київ : Медицина, 2021. - 488 с. *Замовити в Бібліотеці КПІ:* https://opac.kpi.ua/F/?func=direct&doc_number=000636903&local_base=KPI01

Supporting literature:

1. Куц О. Г. *Нормальна фізіологія [Електронний ресурс] : довід. для студентів фарм. ф-тів (заочної форми навчання), спеціальності «Фармація» / О. Г. Куц, Н. П. Жернова, Г. В. Піртя. – Запоріжжя : ЗДМУ, 2017. – 205 с. – Електронні текст. дані (1 файл: 3,29 МБ) // http://dspace.zsmu.edu.ua/bitstream/123456789/6391/1/KushhOG17_Norma_fiz.pdf*
2. *Медична фізіологія за Гайтоном і Голлом: 14-е видання: у 2 томах. / Джон Е. Голл, Майкл Е. Голл. – Elsevier Inc., 2022.*
3. Плиска, О. І. *Фізіологія людини і тварин : підручник для студентів вищих навчальних закладів / О.І. Плиска. - Львів : "Новий Світ-2000", 2018. – 460 с. *Замовити в Бібліотеці КПІ:* https://opac.kpi.ua/F/?func=direct&doc_number=000608813&local_base=KPI01*
4. Терещенко, М. Ф. *Біофізика [Електронний ресурс] : підручник / М. Ф. Терещенко, Г. С. Тимчик, І. О. Яковенко. – Електронні текстові дані (1 файл: 7,06 Мбайт). – Київ : КПІ ім. Ігоря Сікорського ; Політехніка, 2019. – 444 с. // <https://ela.kpi.ua/bitstream/123456789/27589/1/Biophysics.pdf>*
5. *Фізіологія людини і тварини : навчальний посібник / укладачі : Л.С. Язловицька, Г.Г. Савчук ; Міністерство освіти і науки України, Чернівецький національний університет імені Юрія Федьковича. - Чернівці : Чернівецький національний університет імені Юрія Федьковича, 2019. - 215 с. *Замовити в Бібліотеці КПІ:* https://opac.kpi.ua/F/?func=direct&doc_number=000612131&local_base=KPI01*
6. Hall J.E., Hall M.E. *Guyton and Hall Textbook of Medical Physiology. Fifteenth Edition. — Elsevier Philadelphia, PA, 2025. — 1070 p.*
7. Feher J.J. *Quantitative Human Physiology: An Introduction. 2nd Edition. — Academic Press, 2016. — 1008 p. // <https://www.twirpx.com/file/2708214/>*

Educational content

5. Methodology for mastering the academic discipline (educational component)

During the study of the academic discipline, the use of modern educational technologies is provided for. The teaching methods include analytical, deductive, inductive, research-based, partially exploratory methods, as well as the problem-based learning method.

5.1. Information (by sections and topics) on all educational activities

Subject	Program me learning outcomes	Lectures, hrs	Practicals, hrs	Laboratory, hrs	Control measure
Section 1. Systemic Approach in Physiology					
Topic 1.1. Application of systemic approach principles in the study and modeling of interactions between biological and engineering–technical systems.	ПРН 18 ПРН 22	4	4	-	Practical Assignment (PA) No. 1, PA No. 2 Quiz No. 1
Section 2. Quantitative Characteristics of Electromagnetic Processes in the Body					
Topic 2.1. Fundamental-applied, medical-	ПРН 18				PA No. 3

physical, and physico-chemical principles governing the functioning of biological objects. Origin of bioelectrical signals. The role of bioelectrogenesis in excitation. Methods for studying bioelectrogenesis.	ПРН 21 ПРН 22	6	6	-	Quiz No. 2, 3
Topic 2.2. Propagation of excitation in nerve and muscle fibers. Electrical synaptic transmission and chemical synapses.	ПРН 18 ПРН 21 ПРН 22	2	2	-	PA No. 4 Quiz 4
Topic 2.3. Quantitative electrophysiology of the brain. Instrumental methods for studying the bioelectrical activity of the cerebral cortex.	ПРН 18 ПРН 21 ПРН 22	2	2	4	Laboratory work No. 1 Quiz No. 5 Module Test No. 1
Topic 2.4. Quantitative electrophysiology of the heart. Generation of biopotentials and the cardiac conduction system. Formation of the ECG signal.	ПРН 18 ПРН 21 ПРН 22	4	4	4	Laboratory work No. 2 Quiz No. 6,7
Section 3. Quantitative Characteristics of Mass Transfer in the Human Body					
Topic 3.1. The circulatory system: medical and physical principles of functioning, research methods, and instrumental tools for quantitative assessment of function.	ПРН 18 ПРН 21 ПРН 22	10	10	6	PA No. 5, 6, 7, 8 Laboratory work No. 3 Laboratory work No. 4 Quiz No. 8, 9
Topic 3.2. The respiratory system: medical and physical principles of functioning, technologies and equipment for research, methods and tools for quantitative assessment of function.	ПРН 18 ПРН 21 ПРН 22	4	4	4	PA No. 9, 10, 11 Laboratory work No. 5 Laboratory work No. 6 Quiz No. 10, 11
Topic 3.3. The water–electrolyte homeostasis system. Application of artificial biological and biotechnical objects and medical materials in systems for supporting and replacing excretory functions.	ПРН 18 ПРН 21 ПРН 22	4	4	-	PA No. 10 Quiz No. 12 Module Test No. 2
<i>Final Test</i>					
Total hrs		36	36	18	

The alignment of teaching and assessment methods is reflected in the rating-based assessment system, which provides for the assessment of practical assignments, execution and defence of laboratory works, quizzes, a module test, and a final pass/fail assessment (credit).

5.2. Lectures

No.	Lecture title and main questions to be covered	hrs
Section 1. Systemic Approach in Physiology		
1	<p>Application of systemic approach principles in the study and modeling of interactions between biological and engineering–technical systems.</p> <p>Principles of the systemic approach to the study of biological objects. General principles of the functioning of the organism as a system. Human body homeostasis maintenance systems: circulatory, respiratory, digestive, and renal systems. Positive and negative feedback. Application of systems approach principles in solving complex problems characterized by the complexity and non-strict terms.</p>	2

2	The organism as a multi-membrane system. Composition of the body's aqueous compartments. Properties of the membranes separating them. Mechanisms and quantitative assessment of substance transport across membranes.	2
Section 2. Quantitative Characteristics of Electromagnetic Processes in the Body		
3	Fundamental physicochemical principles of the functioning of biological objects. Origin of bioelectrical signals. The role of bioelectrogenesis in excitation. Tissues with excitability properties and their functions. Properties of excitable tissues. Ionic equilibrium potential. Ion channels. Ion pumps and maintenance of the membrane potential. The concept of membrane potential.	2
4	Resting membrane potential. Methods for studying bioelectrogenesis. Calculation of the resting membrane potential. Fick, Nernst, and Goldman–Hodgkin–Katz equations. Electrical equivalent circuit of the cell membrane.	
5	Action membrane potential. Main characteristics of the action potential. The role of potassium, sodium, calcium, and chloride ions in action potential formation. Basic equations. Phases of the action potential. Depolarization, repolarization, and hyperpolarization of the membrane. Current–voltage characteristics of excitable and non-excitabile membranes. Refractoriness. Accommodation. Lability.	2
6	Propagation of excitation in nerve and muscle fibers. Synaptic transmission. Characteristics and directions of electric currents in the action potential region. Generation of impulse discharges during prolonged depolarization. The concept of decrement. Propagation of excitation in myelinated and unmyelinated fibers. Hodgkin–Huxley equations. Chemical synaptic transmission. Synaptic interactions. Electrical synaptic transmission. Features of neuromuscular interaction. Neurotransmitters of neuromuscular transmission.	2
7	Quantitative electrophysiology of the brain. Instrumental methods for studying the bioelectrical activity of the cerebral cortex. Neuronal interactions in the central nervous system. Centers of the nervous system. Functions of the divisions of the central nervous system. Sensory and motor areas of the cerebral cortex. Associative areas of the cerebral cortex. Formation of potentials on the human scalp. Methods for recording potentials. Main rhythms recorded on the electroencephalogram.	2
8	Quantitative electrophysiology of the heart. Maintenance of ionic balance in cardiomyocytes. Membrane depolarization of a cardiomyocyte during action potential formation. Direction of ionic fluxes. The automaticity gradient and its significance for ensuring cardiac function.	2
9	Electrical and magnetic properties of body tissues. Measurement of the magnetic field of the heart. Electrical current generator. Dipoles. Models of electromagnetic interactions. Magnetic properties of body tissues. Fields of bioelectrical generators. Fields of microscopic magnetic particles. Fields arising from non-uniform magnetic susceptibility. Relationship between magnetic and electric fields. Vector motion of dipoles of cardiac potentials and their projection onto the body surface. Formation of the ECG signal. The principle of the equivalent generator.	2
Section 3. Quantitative Characteristics of Mass Transfer in the Human Body		
10	The circulatory system and its components. Composition of blood and plasma. Blood as a non-Newtonian fluid. Density and viscosity of blood plasma and whole blood. Dependence of viscosity on flow velocity and on the formation of cellular clusters. Erythrocyte sedimentation rate.	2

11	<p>Characteristics of heart function as a pump.</p> <p>Cardiac work. Calculation and graphical representation of cardiac work. Determinants of cardiac work: preload and afterload, contractility, myocardial oxygen balance, heart rate, and their interrelationships. Cardiac wall stress and intraventricular pressure from the perspective of Poiseuille's law. Oxygen cost of cardiac work. Frank–Starling law. Contractility.</p>	2
12	<p>Interaction between the heart and blood vessels. Mechanics of blood circulation.</p> <p>Recording of pulse wave propagation and blood flow in vessels. Heart–vessel interaction. Formation and propagation of pulse waves in the cardiovascular system. Relationship and differences between pulsatile blood flow and pulsation of vessel walls. Electrical equivalent circuit of the cardiovascular system. Volumetric and linear blood flow velocity. Continuity equation. Bernoulli equation. Distribution of linear blood flow velocity in different segments of the vascular bed. Poiseuille equation. Laminar and turbulent blood flow.</p>	2
13	<p>Substance transport in the capillary network.</p> <p>Determinants of fluid movement across the capillary membrane. Driving force and velocity of fluid movement. Equation of filtration pressure in the “capillary–interstitial space” system. Shifts in filtration–reabsorption equilibrium under pathological conditions. Deformation of erythrocytes in capillaries.</p>	2
14	<p>Regulation of regional blood flow and systemic hemodynamics. Hemodynamic paradoxes.</p> <p>Cardiac power versus basic hemodynamic equations: mechanisms of reducing energy expenditure. Regulation of local volumetric blood flow. Regulation of cardiac output. Regulation of blood pressure. Regulation of blood volume. Regulation of blood composition.</p>	2
15	<p>Mass transfer characteristics of the lungs.</p> <p>Physiological determinants of external respiration. Spirographic parameters and the work of breathing. Mechanical properties of the airways and lung tissue. Differences between artificial ventilation of the lungs and spontaneous breathing. Gas exchange processes and diffusion properties of the lungs.</p>	2
16	<p>Characteristics of the gas transport function of blood.</p> <p>Gas transport function of erythrocytes and plasma. Oxygen transport properties of hemoglobin. Oxyhemoglobin dissociation curve. Hüfner's constant. Carbon dioxide transport. Interrelationships and regulatory influence of blood gas composition. Calculation of the gas transport function of blood.</p>	2
17	<p>The water–electrolyte homeostasis system.</p> <p>Water movement in the human body. Calculations of the water–electrolyte composition of intravascular, interstitial, and intracellular compartments. Mass transfer and homeostatic function of the kidneys. Renal filtration, absorption, and excretion of substances. Countercurrent mechanism in the loop of Henle. Specific mechanisms of tubular transport. Maintenance of acid–base balance.</p>	2
18	<p>Assessment of renal function. Systems for supporting and replacing excretory functions.</p> <p>Mass transfer and homeostatic function of the kidneys. Methods for assessing renal function. Calculation of glomerular filtration and clearance. Application of artificial biological and biotechnical objects and medical-purpose materials in systems for supporting and replacing excretory functions.</p>	2
Total hrs		36

5.3. Practical Classes

No.	Practical topic and main questions to be covered	hrs
1	Principles of the functioning of the organism as a system/ Systems maintaining human homeostasis: circulatory, respiratory, digestive, and renal systems. Positive and negative feedback.	
2	The organism as a multi-membrane system. Modeling of confined spaces. Mechanisms of substance transport across membranes. Sources and types of energy in cells. Passive transport of uncharged particles: calculation of the partition coefficient, diffusion coefficient, and permeability coefficient.	2
3	Generation and maintenance of bioelectrogenesis. Calculation of the equilibrium membrane potential. Passive ion transport: conditions for equilibrium establishment, determination of equilibrium potentials for different ions. Gibbs–Donnan equilibrium. Active transport of ions across the membrane.	2
4	Resting potential. Action potential. Goldman–Hodgkin–Katz equation. Determination of resting and action potentials. Membrane permeability for major ions in resting and excited states. Equivalent electrical circuit of an excitable membrane. Determination of ion channel conductance at a fixed transmembrane potential.	2
5	Propagation of the action potential along non-myelinated and myelinated nerve fibers. Propagation of the action potential along a non-myelinated nerve fiber. Determination of the potential difference as a function of distance during continuous conduction of excitation along a non-myelinated nerve fiber. Propagation of the action potential along a myelinated nerve fiber. Saltatory conduction of the nerve impulse. Mathematical model of nerve impulse conduction along a neuronal axon (Hodgkin–Huxley model).	2
6	Electrical synaptic transmission and chemical synapse. Electrical synaptic transmission of the nerve impulse. Neurotransmitter-mediated transmission. Excitatory and inhibitory postsynaptic potentials. End-plate potential. Module Test No. 1.	2
7	Generation of biopotentials and the cardiac conduction system. Maintenance of ionic balance in cardiomyocytes. Depolarization of the cardiomyocyte membrane during action potential formation. Direction of ionic currents. Generation of biopotentials and the cardiac conduction system. Comparison of the action potential of a contractile cardiomyocyte and a pacemaker cell.	2
8	Formation of the ECG signal. Cardiac automaticity. Mechanism of automaticity. Vector movement of cardiac potential dipoles and their projection onto the body surface. Formation of the ECG signal. Equivalent generator principle. ECG recorded in the second standard lead: genesis of waves, segments, and intervals.	2
9	Work and power of the heart. Characteristics of cardiac function as a pump. Calculation and graphical representation of cardiac work. Determinants of cardiac performance: preload and afterload, contractility, myocardial oxygen balance, heart rate, and their interrelationships. Myocardial wall tension and intraventricular pressure from the perspective of Poiseuille’s law. Calculation of the oxygen cost of cardiac work..	2

10	Fundamental laws of hemodynamics and calculation of quantitative parameters of blood circulation. Calculation of volumetric and linear blood flow velocities in different segments of the vascular bed, vascular resistance of a vessel or a segment of the vascular bed, and total peripheral vascular resistance.	2
11	Calculation of quantitative parameters of blood circulation. Calculation of blood flow regime, parameters of pulse wave propagation.	2
12	Methods for studying the cardiovascular system. Blood pressure measurement: direct and indirect methods. Blood flow measurement: electromagnetic flowmetry, ultrasonic flowmetry, thermoelectric methods, occlusion plethysmography. Blood pressure measurement. Blood volume measurement.	2
13	Mass transfer characteristics of the lungs. Calculation of external respiration parameters. Volumetric and linear air flow velocities in different parts of the conducting airways and in the alveoli. Aerodynamic resistance. Laminar and turbulent air flow.	2
14	Gas exchange processes and diffusion properties of the lungs. Composition of the alveolar gas mixture and exhaled air. Respiratory quotient. Calculation of lung diffusing capacity. Indirect methods for determining vital capacity and dead space.	2
15	Characteristics of the gas transport function of the blood. Regulation of respiration. Oxyhemoglobin dissociation curve. Hüfner's constant. Calculation of the gas transport function of the blood.	2
16	Methods for studying respiratory function. Respiratory support systems. Methods for analyzing blood and air gases. Spirography. Pneumotachometry. Plethysmography. Oxyhemometry. Spirometry. Regulation of external respiration. Features of respiration under special conditions. Respiratory support systems.	2
17	Assessment of renal function. Calculation of glomerular filtration rate and clearance. Mass transfer and homeostatic functions of the kidneys. Physiological systems ensuring excretion. Regulation of excretion in the human body. Module Test No. 2.	2
18	Systems for supporting and replacing excretory functions. Operating principles of the artificial kidney apparatus. Hemosorption. Plasmapheresis.	2
Total hrs		36

5.4. Laboratory Classes

No.	Title of the Laboratory Work	hrs
1	Bioelectrical Activity of the Cerebral Cortex	4
2	Electrocardiography	4
3	Formed Elements of Blood	2
4	Determination of Systemic Hemodynamic Parameters and the Pumping Function of the Heart	4
5	Study of External Respiration	2
6	Study of the Oxygen Transport Function of Blood	2
Total hrs		18

6. Self-study

Self-study includes: preparation for lectures, practical classes and laboratory work; calculations based on primary data obtained in laboratory classes, solving problems, preparation for the module test; preparation for the final test assessment, etc.

6.1. Types of Self-study work:

No.	Type of Work Assigned for Self-study	hrs
1.	Review of lecture material and study of topics assigned for independent work	14
2.	Problem solving and performing calculations related to the topics of practical assignments	18
3.	Study of materials required for completing, documenting, and preparing for the defense of laboratory works	18
4.	Preparation for the module test No. 1	2
5.	Preparation for the module test No. 2	2
6.	Preparation for the final test assessment	6
Total hrs		60

6.2. Preparation for classroom sessions

Preparation for classroom sessions is carried out according to the course plan, following the references provided to the Platform "Sikorsky": course "Quantitative Physiology", and by completing self-assessment tests available on Moodle. Students are also encouraged to choose a topic and prepare a short report (5 minutes) for one of the practical classes according to the course plan.

6.3. Module test

The module test is divided into two parts (MT 1 and MT 2), each lasting one academic hour. Two hours of self-study are allocated for preparation for MAT 1 and MAT 2.

6.4. Final Test

The Final Test is conducted during the examination session, in the 16th week, after students have completed and defended all laboratory works and passed the module test. Based on the total accumulated rating points for the semester, the student receives the credit without additional examinations if the total score is at least 60 points. Students who meet all admission requirements for the credit but have rating points between 40 and 59, or wish to improve their result, must take a credit test or interview on the credit questions. Six hours of independent work are allocated for preparation for the credit. During remote learning, the credit can be conducted according to the class schedule using the Moodle platform and Zoom for online meetings.

Policy and control

7. Policy of academic discipline (educational component)

7.1. Incentive Points

<i>Encouragement points</i>	
<i>Criterion</i>	<i>Weight (Points)</i>
<i>Preparation of a report on an additional topic for a practical class</i>	<i>1 point</i>
<i>Completion of online courses on topics approved by the instructors</i>	<i>5 points</i>

<i>Preparation of a research paper for participation in a student scientific competition</i>	<i>10 points</i>
<i>Participation in international or national events/competitions, or winning a prize in a university competition related to the course</i>	<i>10 балів</i>
<i>Writing a scientific article on a topic related to the course</i>	<i>10 points</i>
<i>Preparation of a report on an additional topic for a practical class</i>	<i>1 point</i>

However, according to the regulation <https://osvita.kpi.ua/node/37>, section 2.7, the total amount of incentive points cannot exceed 10% of the rating scale.

7.2. Attendance Rules

Attendance at lectures is not mandatory. Attendance at practical classes is recommended, as these sessions include the completion of quick assessments/tests and the defense of practical assignments. Completion and defense of laboratory works are mandatory.

The assessment system is designed to reward student activity as well as the completion of tasks that help develop practical skills and competencies.

7.3. Policy on Deadlines and Retakes

Missed assessments (e.g., defense of practical assignments) can be made up during the next class, provided the assignment scheduled for the current session is completed, or during consultations.

Missed labs can be made up during the next class, provided the assignment scheduled for the current session is completed, or during consultations.

Missed quizzes cannot be made up.

Missed module tests can be made up during consultations.

7.4. Procedure for Appealing Assessment Results

Students have the opportunity to raise any questions related to the assessment process and can expect that these questions will be addressed in accordance with established procedures.

A student has the right to appeal the results of an assessment in accordance with the approved Appeals Policy at Igor Sikorsky Kyiv Polytechnic Institute (approved by Order No. HOH/128/2021 dated 20.05.2021) – <https://osvita.kpi.ua/index.php/node/182>

7.5. Distance Learning

Distance learning is conducted through the “Sikorsky” Distance Learning Platform.

Distance learning via additional online courses on specific topics is permitted if agreed with the students. If only a small number of students wish to take an online course on a particular topic, studying the material through such courses is allowed, but students must complete all assignments required by the course.

The list of courses is proposed by the instructor after determining student interest (since the available course bank is updated almost monthly).

Students must provide a document confirming completion of the online course (if the full course is completed), or submit completed practical tasks from the online course, and pass an oral interview with the instructor on the topics covered. Upon successful completion, students may receive grades for the assessments associated with the studied topics (quick assessments/tests, practical assignments).

Practical assignments are carried out during independent study in distance mode, with the possibility of consulting the instructor via email or social networks.

7.6. Instruction in a Foreign Language

Instruction in English is provided only for international students.

If students wish, it is permitted to study material using English-language online courses on topics corresponding to the content of specific lessons.

7.7. University Policy

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.” More details: <https://kpi.ua/code>.

Standards of Ethical Conduct

The standards of ethical conduct for students and staff are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute.” More details: <https://kpi.ua/code>.

8. Types of Assessment and Rating System

Ongoing assessment is conducted **during classroom sessions** and aims to **evaluate students’ preparedness** for the lessons. During practical classes, it includes **discussion of theoretical questions** as well as **quick assessments/tests during lectures**. It also includes the **module test** and the **completion and defense of the individual assignment (essay)**.

Scheduled Assessment (Calendar Control):

Scheduled assessment is conducted **twice per semester** to monitor the current level of fulfillment of syllabus requirements. There are **two possible outcomes**:

- **Attested (A)** – passed
- **Not Attested (N/A)** – not passed

The result depends on the **number of points accumulated** at the time of the scheduled assessment. In the rating system (RSO), the **minimum number of points required for attestation** is specified for the **first and second scheduled assessments**.

Criteria		First CC (Week 8)	Second CC (Week 14)	
Date of calendar control		<i>8th week</i>	<i>14th week</i>	
Conditions for a positive result in the calendar control	Current rating (points)		≥ 17 points*	≥ 40 points*
	Practical Assignments completion	PA Nos. 1-4	+	+
		PA Nos. 5-8	-	+
	Labs completion	LW Nos. 1-2	+	+
		LW Nos. 3-6	-	+
	Module test	Module test No.1	+	+
Module test No.2		-	-	

*- Points correspond to the cumulative rating accumulated by the student up to the date of the calendar control

Semester Assessment: Final Test (Pass/Fail)

8.1. System for Assessing Control Activities::

No.	Assessment Activity	%	Weight (Points)	Quantity	Total
1.	Quizzes	24	2	12	24
2.	Completion and defense of practical assignments	20	2	10	20
3.	Completion and defense of laboratory works Nos. 1–5	25	5	5	25
4.	Completion and defense of laboratory work No. 6	3	3	3	3
5.	Module test for Section 2 (MT 1)	12	12	1	12
6.	Module test for Section 3 (MT 2)	16	16	1	16
	Total points	100			100
	Total				100
7.	<i>Final Test</i>	100	100	1	100

8.2. Practical Assignments

Weight – 2 points.

Planned Tasks: 10 assignments. Maximum points: 2 points × 10 PA = 20 points.

Assessment Criteria:

Grade	Description	Points
Excellent	The assignment is completed in full and correctly (at least 90% of the required information)	2 points
Good	The assignment is completed incompletely or contains minor errors (at least 75% of the required information)	1,5 points
Satisfactory	The assignment is completed incompletely and/or contains significant errors (at least 60% of the required information)	1 points
Unsatisfactory	The assignment is completed incorrectly (less than 60% of the required information)	0 points

8.3. Quizzes

Weight – 2 points.

Planned Tasks: 12 quizzes. Maximum points: 2 points × 12 quizzes = 24 points.

Assessment Criteria:

Grade	Description	Points
Excellent	Answers are complete and correct (at least 90% of required information)	2 points
Good	Answers are sufficiently complete (at least 75% of required information)	1,5 points
Satisfactory	Answers are incomplete but demonstrate understanding (at least 60% of required information)	1 points
Unsatisfactory	Answers are absent or incorrect (less than 60% of required information)	0 points

8.4. Laboratory Works Nos. 1-5

Weight – 5 points.

Planned Tasks: 5 LW. Maximum points: 5 points × 5 LW = 25 points.

Assessment Criteria:

Grade	Description	Points
Excellent	The work is completed in full and correctly and submitted on time (at least 90% of the required information)	5 points
Good	The work is completed incompletely or contains minor errors (at least	4 points

	75% of the required information) or is submitted after the deadline	
Satisfactory	The work contains significant errors (at least 60% of the required information)	3 points
Unsatisfactory	The work is completed incorrectly, with significant errors (less than 60% of the required information)	0 points

8.5. Laboratory Work No. 6

Weight – 3 points.

Planned Tasks: 1 LW. Maximum points: 3 points × 1 LW = 3 points.

Assessment Criteria:

Grade	Description	Points
Excellent	The work is completed in full and correctly and submitted on time (at least 90% of the required information)	3 points
Good	The work is completed incompletely or contains minor errors (at least 75% of the required information) or is submitted after the deadline	2 points
Satisfactory	The work contains significant errors (at least 60% of the required information)	1,5 points
Unsatisfactory	The work is completed incorrectly, with significant errors (less than 60% of the required information)	0 points

8.6. Module Test for Section 2 (MT 1)

The weighted score for Module Test No. 1 (MT1) is 12 points. It contains 3 tasks, each assessed at a maximum of 4 points. The maximum score for MT1 is 4 points × 3 = 12 points.

Assessment criteria for each MT question:

Grade	Description	Points
Excellent	Answer is complete and correct (at least 90% of required information)	4 points
Good	Answer is sufficiently complete (at least 75% of required information)	3 points
Satisfactory	Answer is incomplete but demonstrate understanding (at least 60% of required information)	2 points
Unsatisfactory	Answer is absent or incorrect (less than 60% of required information)	0 points

8.7. Module Test for Section 3 (MT 2)

The weighted score for Module Test No. 2 (MT2) is 16 points. It contains 4 tasks, each assessed at a maximum of 4 points. The maximum score for MT2 is 4 points × 4 = 16 points.

Assessment criteria for each MT question:

Grade	Description	Points
Excellent	Answer is complete and correct (at least 90% of required information)	4 points
Good	Answer is sufficiently complete (at least 75% of required information)	3 points
Satisfactory	Answer is incomplete but demonstrate understanding (at least 60% of required information)	2 points
Unsatisfactory	Answer is absent or incorrect (less than 60% of required information)	0 points

To obtain the highest grade, a student must complete **practical assignments, quizzes, and module tests** on time, and must also complete and successfully defend all laboratory works in a timely manner.

A student may **appeal a teacher's grade** by submitting a written complaint to the instructor **no later than the day after being informed of the grade**. The appeal will be considered according to the procedures established by the university.

8.8. Semester Assessment of Students

The **Final Test (FT)** is conducted in the 16th week, during the examination session.

<i>Mandatory requirements for admission to the Final Test</i>		<i>Criterion</i>
1	Current rating	RD \geq 40
2	All laboratory works have been completed and defended	> 0 points

Conditions for eligibility for semester assessment:

- Accumulation of at least **40 points**,
- Completion and defense of all the **laboratory works**.

A student **passes the course without additional examinations** if the total points accumulated are **at least 60**.

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

Optional requirements for admission to the pass/fail test:

1. Active participation in practical classes
2. Positive results of the first and second scheduled (calendar) assessments
3. Attendance of lectures

A student who has earned **more than 60 points** during the semester but wishes to **improve their result** may participate in the **credit test or oral questioning** on the topics covered in the course. In this case, the **final result** is based on the points earned in the credit test or oral questioning.

If the grade from the credit test is **lower than the accumulated rating**, a **"strict" rating policy** is applied: the student's previous rating (except points for the semester essay) is **cancelled**, and the final grade is calculated **solely based on the credit test results**. This policy encourages students to take responsibility for their decision to participate in the credit test, critically evaluate their level of preparation, and carefully prepare for the assessment.

Students who have met all the eligibility requirements for the credit but have a rating score of less than 60 points must take the Final Test (FT). The final test is conducted during the last scheduled class of the course.

The **Final Test (FT) assignment** consists of **5 questions** from different sections of the course.

Assessment Criteria for Final Test Questions:

Grade	Description	Points
Excellent	The answer is correct (at least 90% of the required information).	20-18 points
Good	Minor errors are present in the answer (at least 75% of the required information).	17-15 points
Satisfactory	The answer contains deficiencies and some errors (at least 60% of the required information).	14-12 points
Unsatisfactory	The answer is absent or does not meet the requirements for a "Satisfactory" grade.	0 points

The **maximum total points** for the 5 questions are **100 points**: 20 points × 5 questions = 100 points

9. Table of correspondence between rating points and grades according to the university grading scale:

Points	Grade
100-95	Excellent
94-85	Very Good
84-75	Good
74-65	Satisfactory
64-60	Pass
< 60	Unsatisfactory
Failure to meet the admission requirements	Not admitted

10. Additional information on the discipline (educational component)

The Module Test (MT) planned for the discipline, with a total duration of two academic hours, is conducted during two practical classes:

- for Section 2 — in the 5th week;
- for Section 3 — in the 14th week.

The list of questions for preparation for module test, and also for preparation for credit is given in **Appendix 1**.

Distance Learning

Distance learning through participation in additional online courses on specific topics is allowed with the agreement of the students. If only a small number of students wish to take an online course on a specific topic, studying the material through such courses is permitted, but students must complete all assignments required by the course.

The list of courses is proposed by the instructor after students express their interest (since the pool of available courses is updated almost monthly).

A student must provide a document confirming completion of the online course (if the full course is completed) or submit completed laboratory assignments from the online course. Upon successful completion of an oral interview with the instructor on the covered topics, the student may receive grades for the course assessment tasks corresponding to the studied topics (short quizzes/test tasks, laboratory assignments).

Inclusive Education

Permitted

Syllabus of the Academic Discipline:

Compiled by: Associate Professor of the Department of Biomedical Engineering, PhD in Biology, Vovianko Svitlana
Senior Lecturer of the Department of Biomedical Engineering Ovcharenko Hanna

Approved by: Department of Biomedical Engineering (No. 16, June 21, 2024)

Agreed by: Methodological Commission of the Faculty of Biomedical Engineering (Protocol No. 9, June 26, 2024)

The list of questions for preparation for module test, and for final test

1. Properties of the cell membrane of excitable tissues.
2. Origin and maintenance of bioelectrogenesis.
3. Resting potential and action potential. Basic equations.
4. Structure and functions of selective channels.
5. Structure and functions of voltage-gated ion channels.
6. Subthreshold, threshold, and suprathreshold stimuli and their relation to action potential generation.
7. The concept of gradation for excitable and non-excitable membranes (current–voltage characteristics).
8. Fundamentals of the "all-or-none" law and its relationship with the critical membrane potential (CMP).
9. Explain the concept of membrane refractoriness. Causes of absolute and relative refractoriness and supernormality.
10. The concept of accommodation. Causes of this phenomenon.
11. The concept of lability. Causes of this phenomenon.
12. Explain the concept of decrement in excitable membranes. Fundamentals of this phenomenon.
13. Time and length constants, steepness of the rising phase. Basic equations.
14. Features of excitation propagation along myelinated fibers. Basic equations.
15. Features of excitation propagation along unmyelinated fibers. Basic equations.
16. The Hodgkin–Huxley mathematical model.
17. Analyze the differences between electrical and chemical (mediator) transmission of excitation.
18. Structure and functions of the chemical synapse.
19. Mechanisms of generation of excitatory and inhibitory postsynaptic potentials (EPSP and IPSP).
20. Features of neuromuscular transmission.
21. Definition of EEG and the main rhythms recorded on an electroencephalogram.
22. Sensory, motor, and associative areas of the cerebral cortex.
23. Explain the asymmetry of specialization of the left and right cerebral hemispheres.
24. Explain the cause and physiological significance of the prolonged absolute refractory period of working myocardial cells.
25. Explain how the action potential of a pacemaker cell differs from that of a contractile cardiomyocyte.
26. What is the gradient of automaticity in the cardiac conduction system? Provide its quantitative characteristics and explain its physiological significance.
27. Explain the regulatory effects of the sympathetic and parasympathetic nervous systems on the strength and rate of heart contractions.
28. Explain what the integral electrical vector of the heart is. Provide its parameters.
29. Define the electrocardiogram. What assumptions are made when modeling an electrocardiogram?
30. What do the elements of the electrocardiogram represent: P wave, PQ segment, QRS complex, ST segment, T wave?
31. Define Einthoven's triangle. Formulate Einthoven's law.
32. Provide and explain the formula for calculating cardiac work. What is the approximate value of cardiac work at rest?

33. Visualization of the calculation of the Volume–Pressure work of the left ventricle: present and explain the “Volume–Pressure” diagram.
34. Name the main hemodynamic parameters. How are they interrelated? Which hemodynamic parameter is the key one for meeting the metabolic needs of organs and systems?
35. Analyze the arterial blood pressure waveform. What causes the first-, second-, and third-order pressure oscillations?
36. Explain why arterial pressure in the pulmonary circulation is several times lower than in the systemic circulation.
37. Which parameters determine vascular resistance? Justify your answer.
38. Explain laminar and turbulent fluid flow. What determines whether blood flow in a given vascular segment is laminar or turbulent?
39. Explain which mechanisms for reducing resistance are implemented in the cardiovascular system.
40. Provide and explain the formula for calculating effective filtration pressure in muscle capillaries.
41. List and explain the mechanisms of regulation of capillary blood flow.
42. Explain the differences between blood, blood plasma, and serum. How do these differences affect their hemodynamic characteristics?
43. Why do the ribs rise during contraction of the external intercostal muscles, despite each intercostal muscle pulling the lower rib upward and the upper rib downward with equal force? Provide a diagram illustrating this mechanism and the relevant equations.
44. List sequentially the processes that ensure air entry into the lungs during inspiration and air exit from the lungs during expiration. Are inspiration and expiration passive or active (ATP-consuming)? Justify your answer.
45. Name the components that constitute the elastic recoil of the lungs. Does elastic recoil facilitate or oppose inspiration and expiration? Explain the physiological role of surfactant on the inner surface of the alveoli.
46. List and define lung volumes and capacities. Provide their approximate values. Which lung volumes and capacities can be measured by direct methods, and which only by indirect methods? Which methods are used?
47. Explain why the composition of alveolar air during quiet breathing is relatively constant.
48. What factors determine the diffusion of oxygen and carbon dioxide across the alveolar–capillary (air–blood) barrier? Present and analyze the diffusion equation.
49. In what forms are O_2 and CO_2 present and transported in the blood? What determines the amount of dissolved O_2 and CO_2 in arterial and venous blood?
50. Present and analyze the oxyhemoglobin formation and dissociation curve. Which factors promote hemoglobin oxygen saturation in the lungs? Which factors promote oxyhemoglobin dissociation as blood flows through tissues?
51. What does the Hufner number characterize? What is its value?
52. List the features of renal circulation. Explain the myogenic mechanism that stabilizes the glomerular filtration rate under conditions of large fluctuations in systemic arterial pressure (from 80 to 180 mmHg).
53. Provide and explain the formula for calculating the glomerular filtration rate.
54. Present and analyze the formula for calculating effective filtration pressure in the renal glomerulus.
55. Define clearance. Explain the method for studying glomerular filtration using clearance determination.
56. Write and explain the formula for calculating inulin clearance. Compare glomerular filtration rate and clearance for substances that are only filtered, actively secreted, and actively reabsorbed.