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

Department of
Biomedical Engineering

MATHEMATICAL MODELING OF BIOMEDICAL SYSTEMS

Working program of basic discipline (Syllabus)

Requisites for basic discipline	
Level of higher education	***First (bachelor's)***
Branch of knowledge	*16 Chemical engineering and bioengineering*
Specialty	*163 Biomedical Engineering*
Educational program	*Medical Engineering*
Discipline status	*Elective discipline*
Form of study	*full-time*
Year of preparation, semester	*4th course, autumn semester*
The scope of discipline	*4 ECTS credits / 120 hours* *(Lectures – 18 hours, Practical classes – 36 hours, Independent study – 66 hours)*
Semester control / Control measures	*Pass/fail test, term paper, modular test*
Lessons schedule	*https://schedule.kpi.ua/*
Language of instruction	*Ukrainian*
Information about course leader / teachers	***Lecturer:*** *PhD in Engineering, Associate Professor, Associate Professor of the Department of Biomedical Engineering Oksana K. Biloshytska, e-mail: biloshytska.oksana@lll.kpi.ua* ***Practical Classes:*** *Assistant of the Department of Biomedical Engineering Ilona O. Matvieieva, e-mail: i.matveeva-fbmi@lll.kpi.ua*
Course placement	*Sikorsky Distance Learning Platform – Course: Mathematical Modeling of Biomedical Systems (Course code: di62bd)*

Curriculum of the discipline

1. Course Description, Purpose, Subject Area, and Learning Outcomes

The main purpose of the course "Mathematical Modeling of Biomedical Systems" is to develop students' ability to solve complex specialized problems and practical tasks related to the forecasting, classification, and analysis of biomedical data, which requires the application of scientific theories and methods and is characterized by complexity and uncertainty of conditions.

Mathematical tools are widely used in medicine, particularly for diagnostic purposes, solving classification problems, and identifying new patterns for formulating scientific hypotheses. The use of statistical software requires knowledge of the basic methods and stages of statistical analysis, including their sequence, necessity, and sufficiency. Within this course, the emphasis is placed not on the detailed derivation of formulas underlying statistical methods, but on their conceptual essence and rules of application.

General Competencies

Upon completion of the course, students are expected to acquire the following ***general competencies****:*

GC1. *Ability to think abstractly, analyze, and generalize when studying and modeling biomedical processes and systems.*

GC2. *Ability to apply mathematical and statistical methods to solve engineering and applied problems in the biomedical field.*

GC3. *Ability to work with data, including analysis, interpretation, and critical evaluation of results.*

GC4. *Ability to use information technologies and specialized software in professional activities.*

Professional (Specialized) Competencies

Upon completion of the course, students should possess the following ***professional competencies****:*

PC1. *Ability to apply regression analysis methods to describe and forecast biomedical processes and systems.*

PC2. *Ability to use clustering methods for processing and structuring biomedical data.*

PC3. *Ability to apply factor analysis to identify latent factors and reduce the dimensionality of biomedical data.*

PC4. *Ability to use discriminant analysis methods to classify biomedical objects and evaluate classification results.*

Program Learning Outcomes

As a result of studying the course, students will be able to:

PLO1. *Know the basic methods of mathematical modeling and multivariate statistical analysis used in biomedical engineering.*

PLO2. *Be able to construct and analyze regression, clustering, factor, and discriminant models for studying biomedical processes.*

PLO3. *Be able to interpret the results of mathematical modeling and statistical analysis in the context of biomedical tasks.*

PLO4. *Be able to use data analysis software tools to solve practical biomedical engineering problems.*

Contribution to the Educational Program Competencies

This course also contributes to the development of competencies and learning outcomes defined in the educational program approved by Rector's Order No. NON/434/24 dated June 10, 2024.

Integral Competency: *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

GC01 – Ability to apply knowledge in practical situations.

GC02 – Knowledge and understanding of the subject area and professional activity.

GC04 – Skills in using information and communication technologies.

GC06 – Ability to search for, process, and analyze information from various sources.

GC07 – Ability to generate new ideas (creativity).

GC08 – Ability to make reasoned decisions.

Professional Competencies

PC01 – Ability to apply engineering software packages for research, analysis, processing, and presentation of results, as well as for automated design of medical devices and systems.

PC03 – Ability to study and apply new methods and tools for analysis, modeling, design, and optimization of medical devices and systems.

PC05 – Ability to apply physical, chemical, biological, and mathematical methods in the analysis and modeling of the functioning of living organisms and biotechnical systems.

PC11 – 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..

Program Learning Outcomes

PLO 05 - Be able to use databases, mathematical and software tools for data processing and computer modeling of biotechnical systems.

PLO 20 - Knowledge and application of research methods in biomedical engineering, methods and tools for organizing and processing experimental data, statistical methods for modeling and simulating processes and systems of physical and biological nature, modern programming technologies and supporting tools, methods for designing digital and microprocessor-based medical systems.

Teaching Methods

Lectures are conducted using explanatory-illustrative methods, problem-based teaching, and interactive methods aimed at establishing dialogue with students.

Practical classes employ:

1. *Reproductive method for consolidating theoretical knowledge and applying it to practical tasks.*
2. *Partially exploratory (heuristic) method to develop problem-solving strategies.*
3. *Interactive method to engage students in solving tasks and discussing theoretical foundations.*
4. *Presentation and discussion of results using problem-based and interactive approaches.*
5. *Mathematical modeling during practical sessions.*

Students independently study literature and software tools for analysis and forecasting of medical data. In some cases, coursework may evolve into research activities.

2. Prerequisites and Course Position in the Curriculum

The course belongs to the elective component of the curriculum. Prerequisites include:

Knowledge: *higher mathematics (linear algebra, mathematical analysis), probability theory and mathematical statistics, differential equations, elements of mathematical modeling, basic human physiology, engineering mathematics, and signal analysis.*

Skills: *performing algebraic and statistical calculations; analyzing numerical data; constructing graphs and tables; interpreting mathematical and statistical results; formulating simple mathematical models; applying theoretical knowledge to engineering tasks.*

Competencies: *computer literacy; basic skills in MATLAB, Python, R, SPSS, or similar software; data processing and systematization; independent analytical work.*

3. Course Content

Module 1. Regression Data Analysis

Subject 1.1. *Linear regression models. Binary logistic regression.*
Subject 1.2. *Nonlinear regression models. Types of nonlinearity.*
Subject 1.3. *Forecasting system behavior using regression analysis.*

Module 2. Cluster Analysis

Subject 2.1. *Hierarchical clustering.*
Subject 2.2. *k-means clustering.*
Subject 2.3. *Other clustering algorithms.*

Module 3. Factor Analysis

Subject 3.1. *Fundamentals of factor analysis. Factor rotation procedures.*
Subject 3.2. *Criteria for factor analysis applicability. Interpretation of results.*

Module 4. Discriminant Analysis

Subject 4.1. *Canonical discriminant analysis and its justification.*
Subject 4.2. *Construction and interpretation of discriminant functions.*

4. Training materials and resources

Basic literature:

1. *Гороховатський В. О. Методи інтелектуального аналізу та оброблення даних : навч. посіб. / В. О. Гороховатський, І. С. Творошенко ; М-во освіти і науки України, Харків. нац. ун-т радіоелектроніки. – Харків : ХНУРЕ, 2021. – 92 с. Режим доступу: https://openarchive.nure.ua/handle/document/15868*
2. *Методи аналізу даних у психологічних дослідженнях : навчальний посібник / В. М. Краєвський, Я. О. Остапенко, Т. М. Паянок, Н. В. Параниця ; Державний податковий університет. – Ірпінь, 2024. – 144 с. Режим доступу: https://ir.dpu.edu.ua/handle/123456789/3765*
3. *Біостатистика засобами MS EXCEL. Частина 1 [Електронний ресурс] : навч. посіб. для здобувачів ступеня бакалавра за освітньою програмою «Регенеративна та біофармацевтична інженерія» спеціальності 163 Біомедична інженерія / КПІ ім. Ігоря Сікорського ; Мулик О. В., Пригалінська Т. Г., Свистун-Золотаренко Л. О - Київ : КПІ ім. Ігоря Сікорського, 2023. - 364 с. – Режим доступу: https://ela.kpi.ua/handle/123456789/57312*
4. *Мельников О. С. Інтелектуальний аналіз даних : навч.-метод. посібник / О. С. Мельников ; Нац. техн. ун-т "Харків. політехн. ін-т". – Харків : Impress, 2023. – 196 с. Режим доступу: https://repository.kpi.kharkov.ua/handle/KhPI-Press/72877*
5. *Інтелектуальний аналіз даних Data Mining: навчально-методичний посібник. – Кропивницький, ФОП Піскова М. А., 2022. – 112 с. – Режим доступу: https://files.znu.edu.ua/files/Bibliobooks/Inshi80/0059854.pdf*

Additional literature:

1. *IBM SPSS Statistics 26 documentation. – Режим доступу: https://www.ibm.com/docs/en/spss-statistics/26.0.0*
2. *Статистика [Електронний ресурс] : навчальний посібник / О. В. Раєвнєва, І. В. Аксьонова, О. І. Бровко ; за заг. ред. д-ра екон. наук, професора О. В. Раєвнєвої. – Харків : ХНЕУ ім. С. Кузнеця, 2019. – 389 с. – Режим доступу: http://repository.hneu.edu.ua/bitstream/123456789/24523/1/2019%20-%20%D0%A0%D0%B0%D1%94%D0%B2%D0%BD%D1%94%D0%B2%D0%B0%20%D0%9E%20%D0%92.pdf*
3. *Методичні вказівки до виконання комп'ютерних практикумів з навчальної дисципліни «Медична інформатика і кібернетика – 5. Математичне моделювання та симуляція біомедичних систем» для студентів спеціальності 163 «Біомедична інженерія» [Електронний ресурс] / КПІ ім. Ігоря Сікорського ; уклад.: Є. А. Настенко, В. А. Павлов, О. К. Носовець, В. С. Якимчук. – Київ : КПІ ім. Ігоря Сікорського, 2017. – 115 с. – Режим доступу: https://ela.kpi.ua/handle/123456789/19932.*
4. *Мінцер О.П. та ін. Інформаційні технології в охороні здоровя і практичній медицині: У 10 кн. Кн. 5. Оброблення клінічних і експериментальних даних в медицині: Навч. Посіб. / О.П. Мінцер, Ю.В. Вороненко, В.В. Власов. - К.: Вищ. Пік., 2003. - 350 с.*
5. *Albright S. C., Winston W., Zappe C. Data Analysis and Decision Making. Boston : Cengage Learning, 2016. 948 p.*
6. *Data Science & Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data / EMC Education Services. Indianapolis : John Wiley & Sons, Inc, 2015. 432 p.*

Educational content

5. Methods of mastering the discipline (educational component)

No.	Lecture Title and Key Topics (teaching and learning methods, independent study tasks)	General, Professional Competencies and Program Learning Outcomes

No.	Lecture Title and Key Topics (teaching and learning methods, independent study tasks)	General, Professional Competencies and Program Learning Outcomes
Lecture 1	***Introduction to Regression Analysis. Linear Regression Models in Biomedical Engineering*** *Teaching and learning methods: multimedia presentation; examples of biomedical data; graphs and model diagrams; data analysis software (demonstration).* *Independent study: studying the theoretical foundations of linear regression; analysis of examples of linear regression applications in biomedical research; preparation of a brief summary of key concepts.*	*GC1, GC2, GC3, GC4* *PC1* *PLO1, PLO2, PLO3, PLO4*
Lecture 2	***Binary Logistic Regression and Evaluation of Regression Model Quality*** *Teaching and learning methods: multimedia presentation; tables and graphs of classification results; examples of medical diagnostic problems.* *Independent study: studying the methodology of constructing logistic regression models; analysis of model performance indicators (accuracy, sensitivity, specificity); solving typical example-based tasks.*	*GC1, GC2, GC3, GC4* *PC1* *PLO1, PLO2, PLO3, PLO4*
Lecture 3	***Nonlinear Regression Models and Forecasting the Behavior of Biomedical Systems*** *Teaching and learning methods: multimedia presentation; illustrations of types of nonlinearity; examples of predictive models.* *Independent study: studying types of nonlinear regression; analysis of forecasting possibilities for biomedical processes; preparation of examples of predictive model applications.*	*GC1, GC2, GC3, GC4* *PC1* *PLO1, PLO2, PLO3, PLO4*
Lecture 4	***Hierarchical Cluster Analysis of Biomedical Data*** *Teaching and learning methods: multimedia presentation; dendrograms; examples of clustering patients or biomedical signals.* *Independent study: studying algorithms of hierarchical clustering; analysis of dendrograms; comparison of different distance metrics.*	*GC1, GC2, GC3, GC4* *PC2* *PLO1, PLO2, PLO3, PLO4*
Lecture 5	***k-Means Method and Other Cluster Analysis Algorithms*** *Teaching and learning methods: multimedia presentation; graphical illustrations of clusters; demonstration of algorithms.* *Independent study: studying the k-means algorithm; analysis of advantages and disadvantages of different clustering methods; performing clustering of a simple dataset.*	*GC1, GC2, GC3, GC4* *PC2* *PLO1, PLO2, PLO3, PLO4*
Lecture 6	***Theoretical Foundations of Factor Analysis and Factor Rotation Procedures*** *Teaching and learning methods: multimedia presentation; diagrams of factor models; tables of factor loadings.* *Independent study: studying the concepts of factors and latent variables; learning orthogonal and oblique rotation procedures; analysis of examples of factor models.*	*GC1, GC2, GC3, GC4* *PC3* *PLO1, PLO2, PLO3, PLO4*
Lecture 7	***Criteria for the Applicability of Factor Analysis and Interpretation of Results***	*GC1, GC2, GC3, GC4*

No.	Lecture Title and Key Topics (teaching and learning methods, independent study tasks)	General, Professional Competencies and Program Learning Outcomes
	Teaching and learning methods: multimedia presentation; examples of statistical criteria; tables of analysis results. *Independent study: studying criteria for the suitability of factor analysis; interpretation of factor loadings; formulation of conclusions based on analysis results.*	*PC3* *PLO1, PLO2, PLO3, PLO4*
Lecture 8	***Canonical Discriminant Analysis: Theoretical Foundations and Areas of Application*** *Teaching and learning methods: multimedia presentation; diagrams of discriminant functions; examples of classification tasks.* *Independent study: studying the theoretical foundations of discriminant analysis; analysis of conditions for applying the canonical approach; preparation of examples of classification tasks.*	*GC1, GC2, GC3, GC4* *PC4* *PLO1, PLO2, PLO3, PLO4*
Lecture 9	***Construction of Canonical Discriminant Functions and Analysis of Results*** *Teaching and learning methods: multimedia presentation; graphs of class distributions; examples of result interpretation.* *Independent study: studying the stages of constructing discriminant functions; analysis of classification accuracy; generalization of discriminant analysis results.*	*GC1, GC2, GC3, GC4* *PC4* *PLO1, PLO2, PLO3, PLO4*

No.	Title of the class and list of key issues (teaching aids, independent study tasks)	GC, PC and PLO according to the Educational Program
Practical class 1	***Practical work No. 1. Linear Regression of Biomedical Data (Part 1).*** ***Key issues:*** *concept of dependent and independent variables; estimation of linear regression parameters; interpretation of coefficients.* ***Teaching aids:*** *computer, data analysis software, training datasets.* *Independent study: studying the algorithm for constructing a linear regression model.*	*GC1, GC2, GC3, GC4; PC1; PLO1, PLO2, PLO3, PLO4*
Practical class 2	***Practical work No. 1. Linear Regression of Biomedical Data (Part 2).*** ***Key issues:*** *evaluation of model quality; coefficient of determination; residual analysis.* ***Teaching aids:*** *software tools, graphical visualizations. Independent study: analysis of regression modeling results.*	*GC1, GC2, GC3, GC4; PC1; PLO1, PLO2, PLO3, PLO4*
Practical class 3	***Defense of Practical Work No. 1. Practical work No. 2. Binary Logistic Regression (Part 1).*** ***Key issues:*** *construction of a logistic model; interpretation of probabilities; threshold values.* ***Teaching aids:*** *computer, examples of medical diagnostic tasks.* *Independent study: studying the theoretical foundations of logistic regression.*	*GC1, GC2, GC3, GC4; PC1; PLO1, PLO2, PLO3, PLO4*
Practical	***Practical work No. 2. Binary Logistic Regression (Part 2).***	*GC1, GC2, GC3,*

class 4	***Key issues:*** *evaluation of classification quality; confusion matrix; accuracy metrics.* ***Teaching aids:*** *data analysis software. Independent study: analysis of classification results.*	*GC4; PC1; PLO1, PLO2, PLO3, PLO4*
Practical class 5	***Defense of Practical Work No. 2. Practical work No. 3. Nonlinear Regression and Forecasting (Part 1).*** ***Key issues:*** *types of nonlinear models; approximation of experimental data.* ***Teaching aids:*** *computer, examples of nonlinear dependencies. Independent study: studying types of nonlinearity.*	*GC1, GC2, GC3, GC4; PC1; PLO1, PLO2, PLO3, PLO4*
Practical class 6	***Practical work No. 3. Nonlinear Regression and Forecasting (Part 2).*** ***Key issues:*** *forecasting the behavior of biomedical systems; evaluation of forecast accuracy.* ***Teaching aids:*** *software tools, forecast graphs. Independent study: analysis of forecasting models.*	*GC1, GC2, GC3, GC4; PC1; PLO1, PLO2, PLO3, PLO4*
Practical class 7	***Practical work No. 4. Hierarchical Cluster Analysis (Part 1).*** ***Key issues:*** *distance metrics; linkage methods; construction of dendrograms.* ***Teaching aids:*** *computer, dendrogram visualization. Independent study: studying algorithms of hierarchical clustering.*	*GC1, GC2, GC3, GC4; PC2; PLO1, PLO2, PLO3, PLO4*
Practical class 8	***Practical work No. 4. Hierarchical Cluster Analysis (Part 2).*** ***Key issues:*** *interpretation of clusters; selection of the number of clusters.* ***Teaching aids:*** *clustering software tools. Independent study: analysis of cluster analysis results.*	*GC1, GC2, GC3, GC4; PC2; PLO1, PLO2, PLO3, PLO4*
Practical class 9	***Practical work No. 5. k-Means Clustering (Part 1).*** ***Key issues:*** *k-means algorithm; initialization of cluster centers.* ***Teaching aids:*** *computer, graphical illustrations of clusters. Independent study: studying the principles of the k-means method.*	*GC1, GC2, GC3, GC4; PC2; PLO1, PLO2, PLO3, PLO4*
Practical class 10	***Practical work No. 5. k-Means Clustering (Part 2).*** ***Key issues:*** *evaluation of clustering quality; comparison with hierarchical methods.* ***Teaching aids:*** *data analysis software. Independent study: comparative analysis of clustering methods.*	*GC1, GC2, GC3, GC4; PC2; PLO1, PLO2, PLO3, PLO4*
Practical class 11	***Practical work No. 6. Factor Analysis of Data (Part 1).*** ***Key issues:*** *construction of a factor model; determination of the number of factors.* ***Teaching aids:*** *computer, tables of factor loadings. Independent study: studying the fundamentals of factor analysis.*	*GC1, GC2, GC3, GC4; PC3; PLO1, PLO2, PLO3, PLO4*
Practical class 12	***Practical work No. 6. Factor Analysis of Data (Part 2).*** ***Key issues:*** *factor rotation procedures; interpretation of results.* ***Teaching aids:*** *statistical analysis software. Independent study:*	*GC1, GC2, GC3, GC4; PC3; PLO1, PLO2, PLO3, PLO4*

	interpretation of factor loadings.	
Practical class 13	***Practical work No. 7. Discriminant Analysis (Part 1).*** ***Key issues:*** *construction of discriminant functions; conditions for applying the method.* ***Teaching aids:*** *computer, examples of classification tasks. Independent study: studying the theoretical foundations of discriminant analysis.*	*GC1, GC2, GC3, GC4; PC4; PLO1, PLO2, PLO3, PLO4*
Practical class 14	***Practical work No. 7. Discriminant Analysis (Part 2).*** ***Key issues:*** *classification of objects; evaluation of classification accuracy.* ***Teaching aids:*** *data analysis software. Independent study: analysis of discriminant analysis results.*	*GC1, GC2, GC3, GC4; PC4; PLO1, PLO2, PLO3, PLO4*
Practical class 15	***Submission of the term paper. Practical work No. 8. Integrated Analysis of Biomedical Data (Part 1).*** ***Key issues:*** *combination of regression, cluster, and factor analysis.* ***Teaching aids:*** *integrated datasets, software tools. Independent study: preparation for integrated analysis.*	*GC1, GC2, GC3, GC4; PC4; PLO1, PLO2, PLO3, PLO4*
Practical class 16	***Practical work No. 8. Integrated Analysis of Biomedical Data (Part 2).*** ***Key issues:*** *generalization of results; formulation of conclusions.* ***Teaching aids:*** *software tools, graphical materials. Independent study: preparation of generalized conclusions.*	*GC1, GC2, GC3, GC4; PC4; PLO1, PLO2, PLO3, PLO4*
Practical class 17	***Modular control test.*** ***Key issues:*** *assessment of knowledge and skills in regression, cluster, factor, and discriminant analysis.* ***Teaching aids:*** *control tasks, test and calculation problems. Independent study: not provided.*	*GC1, GC2, GC3, GC4; PC1, PC2, PC3, PC4; PLO1, PLO2, PLO3, PLO4*
Practical class 18	***Generalization and preparation for the pass/fail test.*** ***Key issues:*** *revision of key methods; analysis of typical mistakes.* ***Teaching aids:*** *presentation materials, sample tasks. Independent study: revision of course material.*	*GC1, GC2, GC3, GC4; PC1, PC2, PC3, PC4; PLO1, PLO2, PLO3, PLO4*

6. Student Independent Study

Preparation for classroom activities – 45 hours
Preparation for the modular control test – 4 hours
Completion of the individual semester assignment – 11 hours
Preparation for the pass/fail test – 6 hours

Types of Student Activities and Estimated Time Allocation

Type of student activity	***Estimated time (hours)***
Preparation for 1 hour of lectures	*0.5*
Preparation for 1 hour of practical classes	*1.0*
Preparation for the modular control test	*4*
Preparation for the pass/fail test	*6*
Individual semester assignment (term paper / report)	*11*

*One of the main forms of semester assessment during the study of the course **"Mathematical Modeling of Biomedical Systems"** is the preparation of a **term paper (report)**. The term paper is completed during the semester, formatted according to the established requirements, and submitted for assessment during the **15th practical class**.*

*A term paper is a **scientific and technical document** that contains comprehensive and systematized information on a selected topic. It involves the presentation of material based on specially selected literature and independently conducted research. A student may prepare a term paper **only on a topic approved by the instructor**.*

General requirements for the term paper:

- *clarity and logical consistency of the presentation;*
- *persuasiveness of arguments;*
- *conciseness and precision of formulations that exclude ambiguous interpretation;*
- *specificity in presenting research results;*
- *justification of recommendations and proposals.*

The term paper must address:

- *the relevance of the topic and its correspondence to the current state of science, technology, and production-related issues;*
- *justification of the chosen research direction and problem-solving methods, including their comparative evaluation;*
- *analysis and generalization of existing research results;*
- *development of a general research methodology;*
- *the nature and content of performed theoretical studies and calculations, research methods applied;*
- *justification of the need for experimental studies, principles of operation of developed software tools, their characteristics, evaluation of calculation errors, and obtained experimental data;*
- *assessment of the completeness of solving the stated problem;*
- *evaluation of the reliability of obtained results and their comparison with analogous results;*
- *scientific and practical value of the completed work.*

Structure of the term paper:

title page; table of contents; list of symbols, abbreviations, and terms (if necessary); introduction; main body; conclusions; list of references; appendices (if necessary).

Approximate list of term paper topics:

1. *Mathematical modeling of heart rate regulation based on physiological indicators*
2. *Regression models for predicting arterial blood pressure using biomedical data*
3. *Modeling gas exchange processes in the lungs using statistical methods*
4. *Logistic regression in modeling the risk of cardiovascular diseases*
5. *Mathematical modeling of tumor tissue growth based on experimental data*
6. *Cluster analysis of physiological indicators for patient segmentation*
7. *Modeling electrophysiological activity of the heart using multivariate data*
8. *Factor analysis of biomedical parameters as a method for identifying latent physiological factors*
9. *Mathematical modeling of human body thermoregulation processes*
10. *Prediction of blood glucose levels using regression models*
11. *Classification of patient health states using discriminant analysis methods*
12. *Modeling the propagation of nerve impulses in biological tissues*
13. *Clustering of biosignals (ECG, EEG) for detection of pathological conditions*
14. *Mathematical modeling of recovery processes after physical exertion*
15. *Regression modeling of respiratory rate dependence on physiological and external factors*
16. *Factor analysis of indicators of the functional state of the cardiovascular system*
17. *Modeling pharmacokinetic processes in the human body*
18. *Statistical modeling of aging processes based on biomedical data*

19. *Discriminant analysis in modeling diagnostic decisions in biomedical systems*
20. *Integrated mathematical modeling of biological processes using multivariate data analysis*

Title page requirements:

The title page of the term paper must include: the name of the university; the name of the faculty; the name of the department; the name of the specialty; the name of the educational program; the name of the course; the title of the term paper; the student's first and last name; year of study; academic group number; and the year of completion.

Following the title page, a list of abbreviations (if necessary) and a detailed table of contents must be provided. The table of contents should clearly identify the introduction, sections of the main body (main topics to be considered), subsections (if necessary), conclusions, and the list of references. Page numbers indicating the beginning of each section must be aligned on the right. Each section must begin on a new page.

*The total length of the term paper, depending on the selected topic, may range from **25 to 40 pages of the main text** (subject to agreement with the instructor). The length is determined by the student's ability to concisely and comprehensively explain and analyze the obtained information.*

Mandatory requirements:

*All sources of information must be clearly referenced. All numerical data, facts, scientific opinions, quotations, and formulas must include references in the form **[2]**, where the number corresponds to the source in the reference list at the end of the paper. Tables, schemes, graphs, diagrams, and other visual materials must be used.*

*The list of references must contain **at least 10 sources** and be formatted according to the **APA citation style**. All sources must have been published within the **last 5 years**. Preference is given to **foreign (international) sources**. If information is obtained from the Internet, the author, title of the article, and the website address must be indicated, as for printed sources.*

Assessment criteria:

The term paper is evaluated based on the following criteria: logical structure of the outline; completeness and depth of topic coverage; reliability of obtained data; inclusion of practical materials; correctness of conclusions and final results; quality of formatting; justification of the student's own viewpoint in the conclusions.

Submission deadline:

*The final deadline for submitting the term paper for assessment is the **15th practical class**.*

*The term paper is **not checked for plagiarism**, but it must comply with the principles of **academic integrity**. In cases of academic misconduct, the paper is annulled and not assessed.*

Policy and Assessment

7. Course Policy (Educational Component)

Attendance

*Attendance at **practical classes is mandatory**, as these classes include short in-class assessments / test tasks, as well as the completion and defense of practical works. A student is required to be present for the **entire duration of the class**, from the beginning to the end, and to actively participate in the learning process.*

*Attendance at **lectures is not mandatory**.*

*In case of justified absence (illness, official circumstances), the student must inform the instructor in advance or as soon as possible and **make up for the missed class** in accordance with the established procedure.*

Rules of Conduct During Classes

*Students are required to adhere to the principles of **academic ethics** and mutual respect toward the instructor and other students.*

Active participation is encouraged during classes, including answering questions, participating in discussions, and completing learning tasks.

If necessary, students may prepare short oral or written presentations, reports, or analytical texts related to the course topics.

Mobile phones and other personal communication devices must be switched off or set to silent mode.

*The use of laptops, tablets, and mobile devices is permitted **exclusively for educational purposes**, such as completing practical tasks, searching for materials on relevant educational platforms, in open-access sources, or working with educational datasets.*

Missed Assessment Activities

Missed assessment activities (defense of practical works) must be completed during subsequent classes, provided that the task planned for the current class has been completed, or during scheduled consultations.

*Missing the **modular control test** or short in-class assessments / test tasks is **not permitted**. A term paper submitted **after the established deadline** is **not assessed**.*

Rules for the Defense of Practical Works

*A practical work is considered completed provided that the results are submitted on time and **successfully defended orally**.*

The defense of a practical work includes: explanation of problem-solving methods; interpretation of obtained results; and answering the instructor's questions.

*Works completed in violation of the principles of **academic integrity** (plagiarism, copying, use of others' results without proper referencing) are **not admitted for defense and are not assessed**.*

Deadline and Retake Policy

All types of academic work (practical works, term paper, modular control test) must be completed within the deadlines specified in the syllabus.

*Late submission of assignments without a valid reason may result in **refusal to assess the work**.*

*In the presence of justified reasons, a student has the right to **individually agree on a new submission deadline** with the instructor.*

*Retaking assessment activities is carried out in accordance with the regulations, orders, and instructions of **Igor Sikorsky Kyiv Polytechnic Institute**.*

Bonus Points

*Bonus points may be awarded for creative academic activities related to the course (e.g., participation in academic competitions, conferences, scientific contests, preparation of reviews of scientific works or publications, etc.). These bonus points **do not form part of the standard grading scale**.*

*The total number of bonus points **may not exceed 10 points**, and the overall student rating **may not exceed 100 points**.*

Academic Integrity

*The policy and principles of academic integrity are defined in **Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"**. More details are available at: https://kpi.ua/code*

Ethical Standards of 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 are available at: https://kpi.ua/code*

Procedure for Appealing Assessment Results

Students have the right to raise any issues related to assessment procedures and may expect them to be reviewed in accordance with predefined procedures.

*A student has the right to appeal the results of an assessment activity in accordance with the approved **Regulation on Appeals at Igor Sikorsky Kyiv Polytechnic Institute** (approved by Order No. NON/128/2021 dated May 20, 2021): https://osvita.kpi.ua/index.php/node/182*

Inclusive Education

*The course **"Mathematical Modeling of Biomedical Systems"** may be delivered to most students with special educational needs, except for students with severe visual impairments that prevent them from performing tasks using personal computers, laptops, and/or other technical devices.*

Distance Learning

*Distance learning is conducted via the **"Sikorsky" Distance Learning Platform**.*

*Distance learning through additional online courses on specific topics is allowed subject to agreement with students. If only a small number of students express a desire to complete an online course on a particular topic, studying the material through such courses is permitted; however, students must complete **all assignments предусмотрені by the course syllabus**.*

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

The student must provide a document confirming completion of the online course (in case of completing the full course) or submit completed practical tasks from the online course. Upon successful completion of an oral interview with the instructor on the studied topics, the student may receive grades for the assessment activities предусмотрені for the relevant topics (short assessments / test tasks, practical works).

*Practical works and the term paper are completed during students' **independent study in a distance-learning format**, with the possibility of consultations with the instructor via email or social networks.*

Instruction in a Foreign Language

*Instruction in English is provided **only for international students**.*

At the request of students, studying course materials through English-language online courses corresponding to the topics of specific classes is permitted.

8. Types of Assessment and the Rating-Based Grading System (RGS)

The assessment system is focused on awarding points for student engagement and for completing tasks aimed at developing practical skills and competencies.

Assessment System (Continuous Assessment)

No.	Assessment component	%	Weight (points)	Quantity	Total
1	Short in-class assessments / test tasks	18	2	9	18
2	Completion and defense of practical works	56	7	8	56
3	Modular control test	12	12	1	12
4	Term paper (report)	14	14	1	14
5	Pass/Fail assessment work[1]	86	86	1	86

	Total	***100***			***100***

[1] The result is counted toward the overall rating together with the term paper grade if the student has earned fewer than 60 points during the semester or wishes to improve the final grade.

*Failure to complete a continuous assessment activity **in synchronous mode without a valid reason** is graded **0 points**.*

Rules for Assessing the Completion and Defense of Practical Works

- *Each practical work is graded on a **7-point rating scale**.*
- *The **maximum score** for one practical work is **7 points**.*
- *The **minimum passing threshold** is **at least 60%** of the maximum score, which corresponds to **5 points**.*
- *A result below the threshold (**less than 5 points**) is considered **unsatisfactory** and is graded **0 points**.*

Criteria for Assessing a Practical Work

Criterion	***Maximum points***
Correctness of calculations and modeling	*3*
Justification of selected methods and models	*2*
Analysis and interpretation of results	*1*
Oral defense and answers to questions	*1*
Total	***7***

Conditions for Passing a Practical Work

- *A practical work is considered passed if the student scores **5–7 points**.*
- *If **0 points** are awarded, the work **cannot be revised or re-defended** during the academic debt remediation period.*
- *Works completed in violation of **academic integrity principles** are **not accepted** and are graded **0 points**.*

Rules for Assessing the Term Paper

- *The term paper is graded on a **14-point rating scale**.*
- *The **maximum score** for the term paper is **14 points**.*
- *The **minimum passing threshold** is **at least 60%**, which corresponds to **9 points**.*
- *A term paper graded **below 9 points** is considered **not passed** and is graded **0 points**.*

Criteria for Assessing the Term Paper

Criterion	***Maximum points***
Relevance to the topic and completeness of coverage	*4*
Correct application of mathematical models and methods	*4*
Independence of analysis and soundness of conclusions	*5*
Quality of formatting and compliance with academic integrity	*1*
Total	***14***

Conditions for Passing the Term Paper

- *A term paper is considered passed if the student scores **9–14 points**.*
- *If **0 points** are awarded, the student must **revise the paper and resubmit it** before the start of the academic debt remediation period.*
- *Detection of plagiarism or other violations of **academic integrity** results in a grade of **0 points**.*

Pass/Fail Assessment and Application of the Rating System

*Students who have met all eligibility requirements for the pass/fail assessment and have accumulated **60 or more points** receive the corresponding rating grade **without completing an additional semester assessment**.*

*For students who have met all eligibility requirements but have a rating score **below 60 points**, as well as for those who wish to **improve their rating**, the instructor conducts a semester assessment during the examination week in the form of a **pass/fail test or an oral interview**.*

After completing the pass/fail assessment:

- *if the score obtained in the pass/fail assessment is **higher** than the accumulated rating, the student receives the **pass/fail assessment score**;*
- *if the score obtained is **lower** than the accumulated rating, a **"strict" Rating-Based Grading System** is applied: the student's previous rating (excluding points for the individual semester assignment) is annulled, and the final grade is determined **solely based on the pass/fail assessment result**.*

*This approach fosters a **responsible attitude** toward the decision to undertake the pass/fail assessment, encourages students to **critically evaluate their level of preparedness**, and motivates thorough preparation for the final assessment.*

Calendar Control (CC)

*Calendar Control (CC) is conducted **twice per semester** as a monitoring tool to assess the current status of compliance with the syllabus requirements.*

*The purpose of Calendar Control is to **improve the quality of student learning** and to **monitor students' adherence to the academic schedule**.*

Calendar Control Criteria

Criterion	First CC	Second CC
Timing of calendar control	Week 7	Week 13
Conditions for obtaining a positive result		
Current rating	≥ 13 points	≥ 31 points
Completion of practical works: PW No. 1–3	+	+
Completion of practical works: PW No. 4–7	–	+
Short in-class assessments / test tasks: minimum for any 2 lectures	+	–
Short in-class assessments / test tasks: minimum for any 6 lectures	–	+
Modular control test (graded)	–	–
Term paper (graded)	–	–

*In case of detection of **academic misconduct** during the learning process, the corresponding assessment activity **is not credited**.*

Semester Assessment: Pass/Fail Test

Eligibility Requirements for Semester Assessment

*Admission to the semester assessment (pass/fail test) requires **no outstanding academic debts** in practical works and the individual semester assignment (term paper), as well as **completion of the modular control test**.*

Mandatory Eligibility Requirements

No.	Requirement	Criterion
1	Current rating	RD ≥ 40
2	Positive grade for the term paper	More than 9 points
3	All practical works completed and defended	More than 40 points
4	Modular control test completed	More than 7 points

Optional Eligibility Requirements

1. *Positive results in the **first and second Calendar Controls**.*
2. *Attendance of lecture classes.*

Conversion of Rating Points to Grades (University Grading Scale)

Number of points	University grade
95–100	Excellent
85–94	Very good
75–84	Good
65–74	Satisfactory
60–64	Pass
Less than 60	Fail

9. Additional Course Information (Educational Component)

*The list of questions for preparation for the **modular control test** as well as for preparation for the **pass/fail assessment** is provided in **Appendix 1**.*

*Distance learning through the completion of additional **online courses** on specific topics is permitted subject to agreement with students. In cases where only a limited number of students express a desire to complete an online course on a particular topic, studying the material through such courses is allowed; however, students are required to complete **all assignments by the course syllabus**.*

The list of recommended courses is proposed by the instructor after students express their interest, as the pool of available courses is updated almost monthly.

*The student must provide a document confirming completion of the distance course (in the case of completing the full course) or submit completed practical assignments from the distance course. Upon successful completion of an **oral interview with the instructor** on the studied topics, the student may receive grades for the assessment activities provided for the relevant topics (short in-class assessments / test tasks, practical works).*

*In the event of the introduction of an **asynchronous learning mode**, the deadlines for completing assessment activities may be adjusted.*

Course Syllabus

*The course syllabus was prepared by Associate Professor of the Department of Biomedical Engineering, PhD in Engineering, Associate Professor Oksana Biloshytska**,** and Assistant of the Department of Biomedical Engineering Ilona Matvieieva**.***

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

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

List of Questions for Preparation for the Modular Control Test
and for the Pass/Fail Assessment

Section 1. Regression Data Analysis

1. *The concept of mathematical modeling of biomedical processes and its role in biomedical engineering.*
2. *The main stages of constructing a regression model.*
3. *Linear regression model: general form and assumptions.*
4. *Methods for estimating the parameters of linear regression.*
5. *Interpretation of coefficients of a linear regression model.*
6. *Quality metrics of a linear regression model.*
7. *Residual analysis and its importance for assessing model adequacy.*
8. *Binary logistic regression: purpose and fields of application.*
9. *Logistic regression function and its properties.*
10. *Interpretation of logistic regression coefficients.*
11. *Performance metrics of classification models.*
12. *Nonlinear regression models: main types and features.*
13. *The concept of structural and parametric nonlinearity.*
14. *Methods for forecasting the behavior of biomedical systems.*
15. *Limitations of regression analysis in biomedical research.*

Section 2. Cluster Data Analysis

16. *The concept of cluster analysis and its objectives.*
17. *Differences between clustering and classification.*
18. *Distance metrics in cluster analysis.*
19. *Hierarchical cluster analysis: basic principles.*
20. *Linkage methods in hierarchical clustering.*
21. *Dendrogram and its interpretation.*
22. *k-means method: algorithm and conditions of application.*
23. *Selection of the number of clusters in the k-means method.*
24. *Advantages and disadvantages of the k-means method.*
25. *Other clustering algorithms and their general characteristics.*
26. *Evaluation of clustering quality.*

Section 3. Factor Data Analysis

27. *Purpose and objectives of factor analysis.*
28. *The concept of latent variables and factors.*
29. *Main stages of conducting factor analysis.*
30. *Methods for determining the number of factors.*
31. *Factor loadings and their interpretation.*
32. *Factor rotation procedures and their purpose.*
33. *Orthogonal and oblique factor rotations.*
34. *Criteria for the applicability of factor analysis.*
35. *Limitations and errors of factor analysis in biomedical data.*

Section 4. Discriminant Data Analysis

36. *The concept of discriminant analysis and its purpose.*
37. *Differences between discriminant analysis and logistic regression.*

38. *Canonical discriminant analysis: essence and objectives.*
39. *Conditions for applying canonical discriminant analysis.*
40. *Principles of constructing discriminant functions.*
41. *Interpretation of coefficients of discriminant functions.*
42. *Evaluation of discriminant classification quality.*
43. *Typical errors in applying discriminant analysis.*
44. *Practical examples of discriminant analysis applications in biomedical engineering.*
45. *Comparative analysis of regression, cluster, factor, and discriminant methods in biomedical problems.*

Appendix 2 to the Course Syllabus
"Mathematical Modeling of Biomedical Systems"

Program Learning Outcomes (Extended Form)

*As a result of studying the course **"Mathematical Modeling of Biomedical Systems"**, students will be able to achieve the following learning outcomes:*

Learning outcomes		***Alignment of learning outcomes with competencies according to the Educational Program***	
		General competencies (soft skills)	***Professional (specialized) competencies***
PLO1	*Knowledge of the basic methods of mathematical modeling and multivariate statistical analysis applied in biomedical engineering.*	***GC1** – Ability for abstract thinking, analysis, and generalization in the study and modeling of biomedical processes and systems; **GC2** – Ability to apply mathematical and statistical methods to solve engineering and applied problems in the biomedical field.*	***PC1** – Ability to apply regression analysis methods to describe and forecast biomedical processes and systems; **PC3** – Ability to apply factor analysis to identify latent factors and reduce the dimensionality of biomedical data.*
PLO2	*Ability to construct and analyze regression, cluster, factor, and discriminant models for studying biomedical processes.*	***GC2** – Ability to apply mathematical and statistical methods to solve engineering and applied problems in the biomedical field; **GC3** – Ability to work with data, perform analysis, interpretation, and critical evaluation of results.*	***PC1** – Ability to apply regression analysis methods to describe and forecast biomedical processes and systems; **PC2** – Ability to use cluster analysis methods for processing and structuring biomedical data; **PC4** – Ability to use discriminant analysis methods for classifying biomedical objects.*
PLO3	*Ability to interpret the results of mathematical modeling and statistical analysis in the context of biomedical tasks.*	***GC1** – Ability for abstract thinking, analysis, and generalization in the study and modeling of biomedical processes and systems; **GC3** – Ability to work with data, perform analysis, interpretation, and critical evaluation of results.*	***PC2** – Ability to use cluster analysis methods for processing and structuring biomedical data; **PC3** – Ability to apply factor analysis to identify latent factors and reduce the dimensionality of biomedical data; **PC4** – Ability to use discriminant analysis methods for classifying biomedical objects and evaluating classification results.*
PLO4	*Ability to use data analysis software tools to solve practical biomedical engineering problems.*	***GC3** – Ability to work with data, perform analysis, interpretation, and critical evaluation of results; **GC4** – Ability to use information technologies and specialized software in professional activities.*	***PC1** – Ability to apply regression analysis methods to describe and forecast biomedical processes and systems; **PC2** – Ability to use cluster analysis methods for processing and structuring biomedical data; **PC3** – Ability to apply factor analysis to identify latent factors and reduce the dimensionality of biomedical data.*