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

Department of
Biomedical Engineering

METHODS OF MODELING AND ANALYSIS OF BIOMEDICAL PROCESSES AND 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	*Requjired discipline*
Form of study	*full-time*
Year of preparation, semester	*2th course, spring semester*
The scope of discipline	*4 ECTS credits / 120 hours* *(Lectures – 36 hours, Practical classes – 36 hours, Independent study – 48 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: Methods of Modeling and Analysis of Biomedical Processes and Systems*

Curriculum of the discipline

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

The main purpose of the course "Methods of Modeling and Analysis of Biomedical Processes and 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.

Contribution to the Educational Program Competencies

The study of the academic discipline (educational component) "Methods of Modeling and Analysis of Biomedical Processes and Systems" ensures the development of the following competencies and learning

outcomes in accordance with the Educational Program, which was put into effect by the 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

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.

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 01 - The ability to apply knowledge of the fundamentals of mathematics, physics and biophysics, bioengineering, chemistry, engineering graphics, mechanics, materials resistance and strength, properties of gases and liquids, electronics, computer science, signal and image acquisition and analysis, automatic control, system analysis, and decision-making methods at a level necessary for solving biomedical engineering tasks

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

PLO 13 - Be able to analyze signals transmitted from organs to devices and process diagnostic information (signals and images).

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 academic discipline **"Methods of Modeling and Analysis of Biomedical Processes and Systems"** belongs to the cycle of **mandatory educational components**.*

*The **prerequisites** for studying this discipline include the following educational components: **"Higher Mathematics," "Physics," and "Fundamentals of Informatics."***

*The **postrequisites** of this discipline include the following educational components: **"Object-Oriented Programming," "Introductory Practice in Medical Engineering," "Biomedical Systems Design. Interdisciplinary Course Project," "Pre-Diploma Practice," and "Diploma Project."***

3. Course Content

Main Sections and Topics Covered in the Course

Section 1. Fundamentals of Biomedical Data Acquisition and Preprocessing
Topic 1.1. *Purpose and objectives of the discipline*
Topic 1.2. *Sampling methods and grouping of primary data*

Section 2. Regularity and Randomness
Topic 2.1. *Measurement scales and random variables*
Topic 2.2. *Characteristics of random variables*

Section 3. Hypothesis Testing for Location and Dispersion
Topic 3.1. *Statistical hypothesis testing*
Topic 3.2. *Parametric criteria for testing differences*
Topic 3.3. *Nonparametric criteria for testing differences*

Section 4. Relationships Between Variables
Topic 4.1. *Methods for investigating relationships between system parameters and variables*

Section 5. Regression Data Analysis
Topic 5.1. *Linear regression models. Binary logistic regression*
Topic 5.2. *Nonlinear regression models. Types of nonlinearity*
Topic 5.3. *Methods for predicting system behavior using regression analysis*

Section 6. Cluster Data Analysis
Topic 6.1. *Hierarchical cluster analysis*
Topic 6.2. *k-means clustering method*
Topic 6.3. *Other clustering algorithms*

Section 7. Factor Data Analysis
Topic 7.1. *Fundamentals of factor analysis. Rotation procedures in factor analysis*
Topic 7.2. *Criteria for the applicability of factor analysis. Interpretation and results of factor analysis*

Section 8. Discriminant Data Analysis
Topic 8.1. *Canonical discriminant analysis. Rationale for canonical discriminant analysis*
Topic 8.2. *Principles of constructing canonical discriminant functions. Interpretation and results of canonical discriminant analysis*

4. Training materials and resources

Basic literature:

1. *Огнєв, В. А., Помогайбо, К. Г., Трегуб, П. О., Усенко, С. Г., Пересипкіна, Т. В., Мартиненко, Н. М., … та ін. (2023). Соціальна медицина, громадське здоров'я: Біологічна статистика (Т. 1) [PDF]. Харків: ХНМУ. Доступно за адресою: https://www.scribd.com/document/831696716/ПОСІБНИК-БІОСТАТИСТИКА*
2. *Петровська, І. Р., Салига, Ю. Т., & Вудмаска, І. В. (2022). Статистичні методи в біологічних дослідженнях: Навчально-методичний посібник [PDF]. Київ: Аграрна наука. Доступно за адресою: https://www.inenbiol.com/images/stories/Rozrobky/Books/2022/Statistika_2022.pdf*
3. *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*
4. *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*
5. *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*
6. *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*
7. *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. *Гур'янов, В. Г., Лях, Ю. Є., Парій, В. Д., & Короткий, О. В. (2021). Посібник з біостатистики: Аналіз результатів медичних досліджень у пакеті EZR (R-statistics) [PDF]. Доступно за адресою: Біостатистика: Підручники | СЕЗН.ЗНУ*
4. *Голованова І. А. Основи медичної статистики : навч. посіб. для аспірантів та клінічних ординаторів / І. А. Голованова, І. В. Бєлікова, Н. О. Ляхова. – Полтава, 2017. – 113 с. Режим доступу: https://repository.pdmu.edu.ua/handle/123456789/10614*
5. *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.

6. *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.*
7. *Albright S. C., Winston W., Zappe C. Data Analysis and Decision Making. Boston : Cengage Learning, 2016. 948 p.*
8. *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*
Lecture 1	***Subject Area and Professional Activity in Modeling Biomedical Processes and Systems.*** *Purpose, objectives, and place of the discipline in biomedical engineering; role of mathematical methods and computer modeling; overview of biomedical processes as objects of systems analysis.* ***Teaching aids:*** *multimedia presentation; diagrams of biomedical systems; application examples.* ***Independent study:*** *analysis of the educational program; preparation of a summary of key concepts.*	*GC02, GC08; PC05; PPLO01*
Lecture 2	***Acquisition and Primary Processing of Biomedical Data Using ICT.*** *Sources of biomedical data; data structure; measurement errors; preprocessing stages.* ***Teaching aids:*** *multimedia presentation; examples of biomedical datasets; demonstration of software tools.* ***Independent study:*** *analysis of biomedical data examples; description of preprocessing stages.*	*GC04, GC06; PC01; PLO05*
Lecture 3	***Sampling Methods and Grouping of Primary Data in Biomedical Engineering.*** *Population and sample; grouping methods; interval series; data visualization.* ***Teaching aids:*** *multimedia presentation; tables, histograms; data analysis software.* ***Independent study:*** *construction of a sample and data grouping based on a given example.*	*GC06; PC05; PLO05*
Lecture 4	***Measurement Scales and Random Variables in the Analysis of Biomedical Processes.*** *Nominal, ordinal, interval, and ratio scales; discrete and continuous random variables.* ***Teaching aids:*** *multimedia presentation; examples of medical measurements; illustrative diagrams.*	*GC02; PC05; PLO01*

No.	Lecture Title and Key Topics (teaching and learning methods, independent study tasks)	General, Professional Competencies and Program Learning Outcomes
	Independent study: *classification of biomedical indicators by measurement scales.*	
Lecture 5	***Characteristics of Random Variables and Their Interpretation in Biomedical Systems.*** *Central tendency measures; dispersion measures; distribution shape; biomedical interpretation.* ***Teaching aids:*** *multimedia presentation; distribution examples; software-based calculation demonstration.* ***Independent study:*** *computation and interpretation of statistical characteristics.*	*GC06; PC05; PLO05*
Lecture 6	***Regularity and Randomness in Biomedical Processes: Statistical Models.*** *Stochastic nature of biological processes; role of statistical modeling.* ***Teaching aids:*** *multimedia presentation; model diagrams; experimental data examples.* ***Independent study:*** *analysis of randomness examples in biomedical systems.*	*GC02; PC03; PLO01*
Lecture 7	***Statistical Hypothesis Testing in Biomedical Research.*** *Null and alternative hypotheses; significance level; Type I and Type II errors.* ***Teaching aids:*** *multimedia presentation; critical value tables; research examples.* ***Independent study:*** *formulation of statistical hypotheses for given data.*	*GC08; PC11; PLO20*
Lecture 8	***Parametric Criteria for Testing Differences in Biomedical Indicators.*** *t-test; Fisher's criterion; conditions of application.* ***Teaching aids:*** *multimedia presentation; medical experiment examples; software demonstration.* ***Independent study:*** *selection and justification of a parametric test.*	*GC06; PC11; PLO20*
Lecture 9	***Nonparametric Criteria for Hypothesis Testing in Biomedical Engineering.*** *Mann–Whitney, Wilcoxon, Kruskal–Wallis tests; comparison with parametric methods.* ***Teaching aids:*** *multimedia presentation; tables; data examples.* ***Independent study:*** *analysis of the applicability of nonparametric criteria.*	*GC08; PC03; PLO20*
Lecture 10	***Methods for Studying Relationships Between Variables in Biomedical Systems.*** *Correlation analysis; interpretation of coefficients; method limitations.* ***Teaching aids:*** *multimedia presentation; correlation matrices; graphs.* ***Independent study:*** *calculation and analysis of correlations between biomedical indicators.*	*GC06; PC05; PLO13*
Lecture 11	***Linear Regression Models in the Analysis and Forecasting of Biomedical Processes.*** *Model construction; parameter estimation; interpretation.*	*GC02; PC01; PLO05*

No.	Lecture Title and Key Topics (teaching and learning methods, independent study tasks)	General, Professional Competencies and Program Learning Outcomes
	Teaching aids: *multimedia presentation; regression model examples; software environment.* ***Independent study:*** *analysis of linear regression applications in biomedical research.*	
Lecture 12	***Binary Logistic Regression for Medical Data Analysis.*** *Logistic function; coefficient interpretation; model quality assessment.* ***Teaching aids:*** *multimedia presentation; diagnostic task examples; graphs.* ***Independent study:*** *analysis of logistic regression applications in medicine.*	*GC08; PC03; PLO13*
Lecture 13	***Nonlinear Regression Models and Types of Nonlinearity in Biomedical Systems.*** *Polynomial, exponential, and logarithmic models.* ***Teaching aids:*** *multimedia presentation; model examples; software demonstration.* ***Independent study:*** *comparative analysis of linear and nonlinear models.*	*GC06; PC03; PLO05*
Lecture 14	***Methods for Predicting the Behavior of Biomedical Systems Based on Regression Analysis.*** *Forecasting; error assessment; limitations of predictive models.* ***Teaching aids:*** *multimedia presentation; time series; forecast examples.* ***Independent study:*** *analysis of forecasting accuracy.*	*GC08; PC11; PLO20*
Lecture 15	***Hierarchical Cluster Analysis in the Systematization of Biomedical Data.*** *Distance metrics; linkage methods; dendrograms.* ***Teaching aids:*** *multimedia presentation; dendrograms; clustering examples.* ***Independent study:*** *interpretation of hierarchical clustering results.*	*GC06; PC01; PLO05*
Lecture 16	***k-Means Clustering and Other Algorithms.*** *k-means algorithm; selection of the number of clusters; overview of alternative approaches.* ***Teaching aids:*** *multimedia presentation; clustering solutions; software demonstration.* ***Independent study:*** *analysis of the suitability of different clustering algorithms.*	*GC04; PC03; PLO05*
Lecture 17	***Factor Analysis as a Method for Dimensionality Reduction of Biomedical Data.*** *Fundamentals of factor analysis; rotation procedures; applicability criteria.* ***Teaching aids:*** *multimedia presentation; factor matrices; interpretation examples.* ***Independent study:*** *analysis of factor analysis results.*	*GC06; PC05; PLO20*

No.	Lecture Title and Key Topics (teaching and learning methods, independent study tasks)	General, Professional Competencies and Program Learning Outcomes
Lecture 18	**Canonical Discriminant Analysis in Modeling and Classification of Biomedical Systems.** Construction of discriminant functions; classification quality assessment; result interpretation. **Teaching aids:** multimedia presentation; classification task examples; software environment. **Independent study:** synthesis of biomedical data analysis methods and preparation for final assessment.	GC08; PC11; PLO13

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. Application of Sampling Methods and Calculation of Basic Statistical Indicators of Biomedical Data.** Sample formation; calculation of central tendency and dispersion measures; primary interpretation of results. **Teaching aids:** computer; spreadsheet software or data analysis environment; training biomedical datasets. **Independent study:** study of algorithms for calculating statistical indicators.	GC04, GC06; PC01, PC05; PLO05
Practical class 2	**Defense of Practical Work No. 1: Analysis and Visualization of Statistical Characteristics of Biomedical Processes.** Justification of indicator selection; interpretation of results; answers to questions. **Teaching aids:** presentation materials; charts; tables. **Independent study:** preparation for the defense of the practical work.	GC02, GC08; PC11; PLO20
Practical class 3	**Practical Work No. 2. Application of the t-Test and Analysis of Variance for Hypothesis Testing in Biomedical Research.** Hypothesis formulation; testing statistical significance; interpretation of results. **Teaching aids:** computer; statistical analysis software; examples of medical experiments. **Independent study:** analysis of conditions for applying parametric criteria.	GC06, GC08; PC11; PLO20
Practical class 4	**Defense of Practical Work No. 2: Parametric Methods for Hypothesis Testing in Biomedical Engineering.** Justification of criterion selection; analysis of results; answers to questions. **Teaching aids:** result tables; graphical materials. **Independent study:** preparation of well-argued conclusions.	GC02; PC11; PLO20
Practical class 5	**Practical Work No. 3. Application of Nonparametric Criteria in Biomedical Data Analysis.** Mann–Whitney, Wilcoxon, Kruskal–Wallis tests; comparison with parametric methods.	GC06, GC08; PC03; PLO20

	Teaching aids: *computer; statistical tables; training data.* ***Independent study:*** *analysis of the applicability of nonparametric criteria.*	
Practical class 6	***Defense of Practical Work No. 3: Nonparametric Analysis of Biomedical Processes and Systems.*** *Interpretation of results; comparison of methods; answers to questions.* ***Teaching aids:*** *tables; explanatory diagrams.* ***Independent study:*** *preparation of conclusions.*	*GC02; PC11; PLO20*
Practical class 7	***Practical Work No. 4. Correlation Analysis of Relationships Between Parameters of Biomedical Systems.*** *Calculation of correlation coefficients; assessment of strength and direction of relationships; interpretation.* ***Teaching aids:*** *computer; correlation matrices; graphs.* ***Independent study:*** *analysis of correlations between biomedical indicators.*	*GC06; PC05; PLO13*
Practical class 8	***Defense of Practical Work No. 4: Correlation Analysis of Biomedical Data.*** *Justification of results; analysis of method limitations.* ***Teaching aids:*** *graphs; tables.* ***Independent study:*** *preparation of explanations of the obtained results.*	*GC02; PC11; PLO13*
Practical class 9	***Practical Work No. 5. Regression Analysis of Biomedical Processes: Model Construction and Evaluation.*** *Linear regression; parameter estimation; model adequacy analysis.* ***Teaching aids:*** *data analysis software environment; model examples.* ***Independent study:*** *analysis of regression modeling examples.*	*GC04, GC06; PC01, PC03; PLO05*
Practical class 10	***Defense of Practical Work No. 5: Regression Modeling and Forecasting of Biomedical Systems.*** *Interpretation of coefficients; assessment of forecast accuracy.* ***Teaching aids:*** *regression pPLOts; tables.* ***Independent study:*** *preparation of well-argued conclusions.*	*GC08; PC11; PLO20*
Practical class 11	***Practical Work No. 6. Factor Analysis for Dimensionality Reduction of Biomedical Data.*** *Factor extraction; rotation procedures; interpretation of factor structure.* ***Teaching aids:*** *factor matrices; software tools.* ***Independent study:*** *analysis of the applicability of factor analysis.*	*GC06; PC05; PLO20*
Practical class 12	***Defense of Practical Work No. 6: Interpretation of Factor Analysis Results for Biomedical Processes.*** *Factor analysis; formulation of conclusions.* ***Teaching aids:*** *tables; diagrams.* ***Independent study:*** *preparation for the defense.*	*GC02; PC11; PLO20*
Practical class 13	***Practical Work No. 7. Cluster Analysis of Biomedical Data as a Method of Information Systematization.*** *Hierarchical clustering; k-means method; cluster interpretation.*	*GC06; PC01, PC03; PLO05*

	Teaching aids: *dendrograms; software environment.* ***Independent study:*** *analysis of clustering results.*	
Practical class 14	***Defense of Practical Work No. 7: Clustering of Biomedical Processes and Systems.*** *Justification of algorithm selection; result analysis.* ***Teaching aids:*** *graphical materials; tables.* ***Independent study:*** *preparation of conclusions.*	*GC02; PC11; PLO20*
Practical class 15	***Practical Work No. 8. Discriminant Analysis for Classification of Biomedical Objects and Processes.*** *Construction of discriminant functions; assessment of classification quality.* ***Teaching aids:*** *software environment; examples of medical problems.* ***Independent study:*** *analysis of classification results.*	*GC06, GC08; PC03, PC05; PLO13*
Practical class 16	***Defense of Practical Work No. 8: Discriminant Analysis of Biomedical Data.*** *Interpretation of discriminant functions; answers to questions.* ***Teaching aids:*** *tables; graphs.* ***Independent study:*** *synthesis of classification methods.*	*GC02; PC11; PLO20*
Practical class 17	***Submission of the Calculation and Graphical Assignment (CGA). Modular Control Test on Methods of Modeling and Analysis of Biomedical Processes and Systems.*** *Assessment of competency formation; completion of computational and analytical tasks.* ***Teaching aids:*** *individual tasks; computer.* ***Independent study:*** *preparation for the modular control test.*	*GC02, GC08; PC05; PLO01, PLO20*
Practical class 18	***Generalization and Systematization of Methods for Analysis and Modeling of Biomedical Processes and Systems.*** *Comparison of methods; application areas; typical errors.* ***Teaching aids:*** *summary tables; diagrams.* ***Independent study:*** *preparation for the final assessment.*	*GC02; PC03; PLO20*

6. Student Independent Study

Preparation for classroom activities – 28.8 hours
Preparation for the modular control test – 4 hours
Completion of the individual semester assignment – 9.2 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	*0.3*
Preparation for 1 hour of practical classes	*0.5*
Preparation for the modular control test	*4*
Preparation for the pass/fail test	*6*
Individual semester assignment (term paper / report)	*9.2*

One of the main forms of semester assessment in the course ***"Methods of Modeling and Analysis of Biomedical Processes and Systems"*** *is the completion of a* ***Calculation and Graphical Assignment (CGA)****.*

*The CGA is carried out throughout the semester, formally prepared, and submitted for evaluation during **Practical Class 17**.*
*The Calculation and Graphical Assignment is an **individual comprehensive task**, the purpose of which is to assess the student's ability to:*

- *apply **mathematical, statistical, and computational methods** for the analysis of biomedical data;*
- *perform **modeling and analysis of biomedical processes and systems**;*
- *interpret computational results in the context of **biomedical engineering**;*
- *use **software tools** for data processing, visualization, and analysis.*

*The CGA must incorporate **all core methods** studied during the practical classes.*

Mandatory Content Requirements for the CGA
*The Calculation and Graphical Assignment must include the following **structural elements**:*

- ***Introduction** (justification of the relevance of the chosen topic; formulation of the aim and objectives of the work; brief description of the object and subject of the study; indication of the applied analysis methods).*
- ***Description of the Initial Biomedical Data** (source or model of biomedical data generation; description of variables, measurement scales, and sample size; characterization of potential errors and data limitations).*
- ***Practical Section**, which includes:*
  - *primary statistical data processing;*
  - *statistical hypothesis testing;*
  - *analysis of relationships between variables;*
  - *regression modeling of biomedical processes;*
  - *application of multivariate analysis methods.*
- ***Generalization of Results and Conclusions**.*
- ***List of References**.*

Formatting Requirements for the CGA

- *the assignment must be prepared **in electronic form in the state language**;*
- *the presence of **tables, graphs, and diagrams** is mandatory;*
- *all formulas, figures, and tables must be **numbered and titled**;*
- *results must be accompanied by **analytical explanations**, not only calculations;*
- *the **software environment** used must be specified in the text of the work.*

Recommended Topics for Calculation and Graphical Assignments

1. *Statistical analysis and modeling of cardiovascular system indicators.*
2. *Analysis of biomedical signals using correlation and regression methods.*
3. *Modeling the influence of physiological factors on respiratory system parameters.*
4. *Statistical hypothesis testing in studies of the effectiveness of medical interventions.*
5. *Regression-based forecasting of patients' biomedical indicators.*
6. *Clustering of biomedical data for identifying patient groups.*
7. *Factor analysis of multiparametric biomedical systems.*
8. *Discriminant analysis in medical diagnostic tasks.*
9. *Comprehensive analysis of biomedical processes using multivariate methods.*
10. *Modeling and analysis of experimental biomedical data using modern ICT tools.*

Title Page and Structure Requirements
*The **title page** of the CGA 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 and professional program; the name of the academic discipline; the CGA topic; the student's surname and first name; year of study; academic group number; and year.*

*The title page is followed by a **list of abbreviations** (if necessary) and a **detailed table of contents**, which should clearly indicate the introduction, main sections (key topics addressed), subsections (if applicable), conclusions, and references. Page numbers indicating the beginning of each section must be specified on the right. Each section must start on a new page.*
*The **total length of the CGA** may range from **25 to 40 pages of main text** (subject to approval by the instructor). The volume of the work is determined by the student's ability to present and analyze information concisely yet comprehensively.*

Academic Integrity and Referencing Requirements
*A mandatory requirement is **clear and accurate referencing of information sources**. All numerical data, facts, scientific opinions, quotations, and formulas must be accompanied by references in the form **[2]** (where the number corresponds to the source listed in the references section).*
*The use of **tables, diagrams, charts, and graphs** is required. The **list of references** must include **at least 10 sources**, formatted according to the **APA citation style**, published within the **last five years**. Preference is given to **international (foreign-language) sources**.*
If information is obtained from Internet sources, the author and title of the article must be indicated, followed by the website address, in accordance with standard referencing rules.

Assessment and Submission
The CGA is assessed based on:
- *logical structure of the work;*
- *completeness and depth of topic coverage;*
- *reliability of the obtained data;*
- *inclusion of practical materials;*
- *correctness of conclusions and interpretations;*
- *quality of formatting;*
- *justification of the student's own perspective in the conclusions.*

*The **deadline for submission** of the CGA for evaluation is **Practical Class 17**.*
*The CGA is **not subject to plagiarism detection software**, but it must fully comply with the principles of **academic integrity**. In cases of academic misconduct, the work is **annulled and not reviewed**.*

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 **"Methods of Modeling and Analysis of Biomedical Processes and 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	1	18	18
2	Completion and defense of practical works	56	7	8	56
3	Modular control test	10	10	1	10
4	Calculation and Graphical Assignment	16	16	1	16
5	Pass/Fail assessment work[1]	84	84	1	84
	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 CGA

- *The CGA is graded on a **16-point rating scale**.*
- *The **maximum score** for the CGA is **16 points**.*
- *The **minimum passing threshold** is **at least 60%**, which corresponds to **10 points**.*
- *CGA graded **below 10 points** is considered **not passed** and is graded **0 points**.*

Criteria for Assessing the CGA

Criterion	Maximum points
Relevance to the topic and completeness of coverage	4
Correct application of mathematical models and methods	5
Independence of analysis and soundness of conclusions	5
Quality of formatting and compliance with academic integrity	2
Total	**16**

Conditions for Passing the CGA

- *CGA is considered passed if the student scores **10-16 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	≥ 30 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 5 lectures	+	–
Short in-class assessments / test tasks: minimum for any 10 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 (CGA), 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 CGA	More than 10 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)*

Appendix 1 to the Course Syllabus
"Methods of Modeling and Analysis of Biomedical Processes and Systems"

List of Questions for Preparation for the Modular Control Test

and for the Pass/Fail Assessment

1. *The purpose, objectives, and role of the course "Methods of Modeling and Analysis of Biomedical Processes and Systems" in the education of a biomedical engineer.*
2. *The concept of a biomedical process and a biomedical system as objects of modeling.*
3. *The role of mathematical modeling in the analysis of biological and medical processes.*
4. *Stages of acquisition and preprocessing of biomedical data.*
5. *Main sources of biomedical data and their characteristics.*
6. *The concepts of population and sample in biomedical research.*
7. *Methods of sample formation and grouping of primary biomedical data.*
8. *Measurement scales and their application in biomedical engineering.*
9. *Random variables and their role in modeling biomedical processes.*
10. *Basic statistical characteristics of random variables and their biomedical interpretation.*
11. *The concepts of regularity and randomness in biological systems.*
12. *Types of statistical distributions most commonly encountered in biomedical data.*
13. *The concept of a statistical hypothesis and its role in biomedical research.*
14. *Null and alternative hypotheses: formulation and examples.*
15. *Significance level and statistical power of a test.*
16. *Type I and Type II errors in statistical hypothesis testing.*
17. *The essence of parametric hypothesis testing criteria.*
18. *Student's t-test: conditions of application and interpretation of results.*
19. *Analysis of variance (ANOVA): purpose and main stages.*
20. *Advantages and limitations of parametric methods in biomedical analysis.*
21. *The essence of nonparametric hypothesis testing criteria.*
22. *The Mann–Whitney test: purpose and application examples.*
23. *The Wilcoxon test and areas of its application.*
24. *Comparison of parametric and nonparametric analysis methods.*
25. *The concept of relationships between variables in biomedical systems.*
26. *Correlation analysis: essence, objectives, and limitations.*
27. *Correlation coefficients and their interpretation in biomedical research.*
28. *The concept of causality and its distinction from correlation.*
29. *Limitations of correlation analysis in biomedical data.*
30. *Prerequisites for the application of regression analysis.*
31. *The essence of regression analysis in modeling biomedical processes.*
32. *Linear regression models and their main parameters.*
33. *Methods for estimating parameters of linear regression models.*
34. *Interpretation of regression model coefficients.*
35. *Assessment of adequacy and quality of regression models.*
36. *Binary logistic regression and its application in medicine.*
37. *The concept of nonlinear regression models and types of nonlinearity.*
38. *Advantages and limitations of nonlinear models in biomedical analysis.*
39. *Prediction of biomedical system behavior using regression models.*
40. *Forecasting errors and methods for their evaluation.*
41. *The concept of multivariate analysis of biomedical data.*
42. *Factor analysis: purpose, basic concepts, and application areas.*
43. *Criteria for the applicability of factor analysis.*
44. *Factor rotation procedures and their interpretation.*

45. *Cluster analysis as a method for systematizing biomedical data.*
46. *Hierarchical cluster analysis and its characteristics.*
47. *The k-means method: algorithm and conditions of application.*
48. *Comparison of different clustering algorithms.*
49. *Interpretation of clustering results in biomedical engineering.*
50. *Limitations of cluster analysis of biomedical data.*
51. *The essence of discriminant analysis in classification tasks.*
52. *Canonical discriminant analysis and its purpose.*
53. *Principles of constructing discriminant functions.*
54. *Assessment of the quality of discriminant models.*
55. *Comparison of discriminant analysis with other classification methods.*
56. *The role of software tools in modeling biomedical processes and systems.*
57. *Requirements for correct presentation of biomedical analysis results.*
58. *Academic integrity in performing calculation and graphical assignments.*
59. *Integrated use of statistical methods in biomedical engineering.*
60. *Prospects for the application of modeling and analysis methods in modern biomedical engineering.*

Appendix 2 to the Course Syllabus
"Methods of Modeling and Analysis of Biomedical Processes and Systems"

Program Learning Outcomes (Extended Form)

As a result of studying the course ***"Methods of Modeling and Analysis of Biomedical Processes and 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***
PLO01	*The ability to apply knowledge of the fundamentals of mathematics, physics and biophysics, bioengineering, chemistry, engineering graphics, mechanics, materials resistance and strength, properties of gases and liquids, electronics, computer science, signal and image acquisition and analysis, automatic control, system analysis, and decision-making methods at a level necessary for solving biomedical engineering tasks*	*GC02 – Knowledge and understanding of the subject area and professional activity.* *GC08 – Ability to make reasoned decisions.*	*PC05 – Ability to apply physical, chemical, biological, and mathematical methods in the analysis and modeling of the functioning of living organisms and biotechnical systems.*
PLO05	*Be able to use databases, mathematical and software tools for data processing and computer modeling of biotechnical systems*	*GC04 – Skills in using information and communication technologies.* *GC06 – Ability to search for, process, and analyze information from various sources.*	*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.*
PLO13	*Be able to analyze signals transmitted from organs to devices and process diagnostic information (signals and images).*	*GC02 – Knowledge and understanding of the subject area and professional activity.* *GC06 – Ability to search for, process, and analyze information from various sources.*	*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.*
PLO20	*Knowledge and application of research methods in biomedical engineering, methods and tools for organizing and processing experimental data, statistical*	*GC06 – Ability to search for, process, and analyze information from various sources.*	*PC03 – Ability to study and apply new methods and tools for analysis, modeling, design, and optimization of medical devices and systems.* *PC11 – Ability to develop, plan, and*

	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.	*GC08 – Ability to make reasoned decisions.*	*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.*