Biomedical engineering, specialization Medical Informatics (1st degree)

Diploma examination topics – current list

Block: Medicine

No	Related course	Topics
1	Biophysics	The significance of the hydrophobic effect in biological systems. Structure and function of biological membranes. Fluid dynamics in the human body. Mass flow between the cell and its environment.
2	Anatomy for Biomedical Engineers	Physical and biological properties of bones. Describe the sequence of events in one complete cardiac cycle. List important functions of the liver and briefly explain their significance. Name and briefly describe the five major body cavities in the human body.
3	Propaedeutics of Medical Sciences	Explain the difference between etiology and symptomatology in the context of disease. What are the main imaging modalities used for diagnosing pathologies of the digestive tract? What are the main types of grafts used in transplantation, and how do they differ? What is the difference between oncogenes and tumor suppressor genes?
4	Introduction to Biomedical Optics and Biophotonics	Explain the laws of reflection and refraction (Snell's law), as well as the concept of refractive index. Compound Optical Microscope (Thin Lens Approximation): Explain the qualitative process of image formation and provide a quantitative analysis of image magnification. How is luminescence used in medical diagnostics, and what are its main applications? How is wave optics utilized in medical imaging and diagnosis.
5	Introduction to Physiology	What is homeostasis - describe its mechanism of action; give two examples; Action potential and graded potentials - describe their mechanism of action; How does the heart pump blood and how the blood pressure is regulated. What are the main processes involved in urine production ?
6	Medical Imaging Techniques	Explain the concept of hybrid imaging systems in nuclear medicine. Why are they beneficial? List and describe the principles of medical imaging techniques using ionizing radiation. Explain the fundamental principle behind MRI, specifically mentioning hydrogen nuclei, magnetic field, and radiofrequency waves. Discuss the role of artificial intelligence in medical imaging. Provide examples of applications.
7	Legal and Ethical Aspects in Biomedical Engineering	Software as a medical device in relation to a regulatory framework that establishes the technical requirements for medical devices and the conditions for their use. MDD vs MDR – differences in medical device market regulations. Is notified body needed for declaration of conformity of the medical device?

Block: Programming

No	Related course	Topics
8	Introduction to Programming	Overview of the Java platform architecture, including the Java Runtime Environment (JRE), Java Virtual Machine (JVM), and the role of bytecode in enabling platform independence. Overview of programming paradigms and styles, including procedural, object-oriented, and declarative programming, with examples of their key characteristics and typical use cases. Explanation of common sorting algorithms, including bubble sort, selection sort, and insertion sort, with discussion of their logic and time complexity.
9	Introduction to Object Oriented Programming	Fundamental concepts of Object-Oriented Programming in Java, including encapsulation, inheritance, polymorphism, abstraction, and their practical implementation using classes, objects, methods, and interfaces. Overview of exception handling in Java, covering checked and unchecked exceptions, try-catch-finally blocks, and custom exception creation. Principles and practices of unit testing, including the creation of test cases, use of assertions, test lifecycle management, and testing of data structures such as generic collections. Overview of generic data structures and collections in Java, including their purpose, benefits of type parameterization, common collection types (such as List, Set, and Map), and typical operations performed on these collections.
10	Programing in Python	Overview of programming paradigms and styles in Python, including procedural, object-oriented, and functional programming, with examples of their key characteristics and typical use cases. Fundamental concepts of Object-Oriented Programming in Python, including encapsulation, inheritance vs. composition, dynamic polymorphism (duck typing), abstraction, and their practical implementation using classes, objects, special (dunder) methods, properties, and Abstract Base Classes. Overview of exception handling in Python, covering rationale, control flow, major built-in exception classes, raise statements, and try-except-else-finally blocks. Principles and practices of unit testing in Python, including test focus (typical, edge, and error cases), and the creation of test cases using assertions and frameworks like unittest or pytest.

Block: Computer Science

No	Related course	Topics
11	Databases	Database systems – architecture, historical development, system generations, and classification of current database architecture types with relevant examples. Description of database models, focusing on the relational data model and NoSQL models, including their characteristics, use cases, and examples. Overview of database security measures and their application in healthcare systems, including user authentication, authorization, roles, privileges, use of views for access control, protection against common attacks (such as SQL injection), and ensuring data confidentiality, integrity, and availability in electronic health records and hospital management systems (HIS), with attention to data structure, privacy requirements, system integration, and typical functionalities.
12	Mobile Application Development	Description of the Android activity lifecycle and its significance in mobile application development. Discussion of key lifecycle methods and strategies for managing state and resources effectively. Overview of asynchronous task handling in Android, with emphasis on Kotlin coroutines. Comparison with traditional threading approaches and discussion of lifecycle-aware background processing. Principles of designing effective and user-friendly interfaces in Android applications. Considerations for usability, consistency, responsiveness, accessibility, and adaptability to different screen sizes.
13	Network Technologies	Overview of computer networks, including common network topologies, fundamental definitions, and the ISO/OSI reference model with its seven layers. Description of the TCP/IP model and key protocols associated with each layer. Design principles of computer networks, including selection of appropriate topologies and protocols for a given scenario. Discussion of common network security concerns, along with strategies to mitigate these issues. Overview of modern web application development using React for the frontend, including key concepts. Description of the Spring Framework for backend development, focusing on its role in building RESTful APIs and integration with frontend technologies.
14	Software Engineering	Define the main phases of the software development life cycle (SDLC). Describe the fundamental characteristics of the waterfall and agile approaches. Explain the key differences between these two approaches in terms of flexibility, risk management, and stakeholder involvement. Explain the role and importance of version control systems (VCS) in modern software development. Define continuous integration (CI) and continuous delivery (CD). Discuss how CI/CD practices help prevent common software development issues such as integration conflicts and deployment errors. Define and explain the following practices used to ensure software quality: code review, refactoring, unit testing, system testing, acceptance testing. For each practice, describe what is its purpose, who typically performs it, and when it is usually applied in the development process.

15	Computer Science in Medicine* (elective course)	Discuss the role of mobile technologies (mHealth) in healthcare. Provide specific examples of applications and the benefits of using mobile tools in diagnosis and treatment. Critically evaluate the use of artificial intelligence and machine learning in medical diagnostics. List at least two example applications and discuss their advantages and limitations. Analyze the application of biomolecular modeling techniques in drug discovery. Describe the molecular methods and computational tools used during the modeling process.

Block: Electronics

No	Related course	Topics
16	Introduction to Medical Electronics 1	Components of linear and stationary electrical circuits: current-voltage characteristics of perfect and real elements. Basic relationships between currents and voltages in linear electrical systems. Theorems and methods for analysing them. How the steady-state behaviour of linear systems on sinusoidal stimulation is described. What parameters are then used to describe the properties of passive elements? Please describe a step response of the integrating and differentiating RC circuits.
17	Principles of Medical Electronics 2	Amplifiers, their models and parameters. Operational amplifier: its properties and basic applications. An instrumentation amplifier. Digital circuits: examples of combinational and sequential logic circuits. Semiconductor diodes, their properties and exemplary applications. Please describe the properties of selected photoelectric sensors.
18	Microcontrollers	What functional elements does a typical microcontroller contain? What can a microcontroller be used for in the construction of measuring, diagnostic and therapeutic devices? Subroutines: call and return from the subroutine. A stack and its use.
19	Electromedical Instrumentation	Discuss the basic technique components for biopotential measurement (electrode, amplifier, filter). Characterize the measurement technique for 1) circulatory system, 2) auditory system 3) respiratory system 4)nervous system and 5) musculatory system. Describe the safety codes for electromedical equipment. Characterize inductive coupling and capacitive coupling phenomenon’s.
20	Measurement systems	Topologies used in measurement systems, their properties and examples of implementation using wired and wireless communication interfaces. Local communication with digital measurement transducers - characteristics and organization of transmission in I2C and SPI interfaces. Analog-to-digital processing in measurement systems. The most commonly used processing methods and their properties.

Block: Signal And Images Processing

No	Related course	Topics
21	Digital Signal Processing	Principles and practical aspects for setting the sampling frequency of a signal. Principles of digital filtering. FIR vs IIR filters. Spectral represenation of signals. The role of amplitude and phase spectra. Are negative frequencies in a spetral representation of a signal real or just a mathematical formulation? Explain the uncertainty principle in signal processing. Demonstrate examples on a time–frequency plane.
22	Computer Graphics* (elective course)	What is Render engine? Rasterization. Raytracing. Pathtracing. Physical basis of those approaches. Differences between them. How are raster and vector graphics represented? What are advantages and disadvantages of those two representations. What is DPI and image resolution? 3D computer graphic pipeline. From modelling to animation - description, approaches, examples.
23	Advanced Imaging Techniques* (elective course)	Fundamentals of biomedical image processing, including techniques for image enhancement, filtering, and noise reduction; the role of wavelets in image analysis; and methods for feature extraction, segmentation, and systematic validation using biomedical image datasets. Application of machine learning and deep learning techniques in biomedical image analysis, focusing on approaches for segmentation and classification, including traditional algorithms and convolutional neural networks.

Block: Modeling And Numerical Methods

No	Related course	Topics
24	Numerical Methods	Sources of errors in numerical calculations. Numerical differentiation. Numerical integration.
25	Modelling of Biological Systems	Practical implementation of statistical models, using Monte Carlo methods, QSAR, Markov chains etc. as examples. Force fields in MD simulations—what they are and what role they play; provide examples of well-known solvent models and describe them. Advantages and disadvantages of the in silico approach.
26	Introduction to Bioinformatics* (elective course)	What is a sequence alignment? Reasons and methods to calculate it. What is a phylogenetic tree? What method could be used to obtain it? What is currently the best method to calculate an unknown protein structure and which methodology does it use ? Name other classical methods.
27	Time Series Analysis* (elective course)	Time series forecasting algorithms (exponential smoothing, SARIMAX, and ML regressors) Model selection and information criteria. Neural networks in time series forecasting

28	Complex Systems* (elective course)	What is the percolation model and the percolation threshold? What physical and biological phenomena can be described using the percolation model? What is a complex network? List the basic characteristics of such networks and provide examples of biological complex networks. What methods can be used for their representation and analysis? What is a cellular automaton? Discuss a selected cellular automaton and the possible applications of this model for describing real-world phenomena.
29	Statistical Methods in Bioengineering* (elective course)	Is testing normality/Gaussianity of data useful? List the basic characteristics of such networks and provide examples of biological complex networks. What methods can be used for their representation and analysis? How to determine whether a given correlation value is statistically significant? Give an example of a multilinear regression model that can be reduced.
30	Artificial Intelligence 1* (elective course)	Fundamental architectures of modern neural networks (including multilayer perceptrons, convolutional neural networks, and transformers): key characteristics and structural features; learning mechanisms and training processes; typical applications and use cases in biomedicine; notable examples and practical implementations. Data processing in machine learning: essential preprocessing steps, including methods for data cleaning, splitting, handling class imbalance, transformation, and encoding; overview of key dimensionality reduction algorithms (e.g., PCA, UMAP) and clustering methods (e.g., k-means, DBSCAN); applications to biomedical data Unblackboxing Artificial Intelligence: modern methods for explainability (e.g., LIME, SHAP, Grad-CAM, counterfactuals) and uncertainty quantification (Reliability diagrams, Expected Calibration Error, e.g., MC Dropout, conformal predictions); basic concepts, expected outcomes, scope of applicability, and sample applications in biomedicine. Evaluation of knowledge representation in AI: for a given biomedical problem, analyze the provided representation focusing on the type of simplification applied to the represented object, the assumptions made and their justification, the types of inference it supports, computational efficiency, and ease of communication.