NATIONAL TECHNICAL UNIVERSITY OF UKRAINE
«IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE»
FACULTY OF BIOMEDICAL ENGINEERING

Approved by

Head of the Attestation Commission of
the Faculty of Biomedical Engineering

Dean Vitalyi MAKSYMENKO

« 25 » April 2022 p.

STAMP

PROGRAM OF

Comprehensive professional examination

for educational professional program

Master "Medical engineering"

specialization 163 Biomedical engineering

Program approved by

Department of biomedical engineering

Protocol № 11 from « 15 » « April » 2022 year

Head of the department Vladislav SHLYKOV

Kyiv – 2022

INTRODUCTION

Admission to the educational professional program for the second (Master's) level of higher education "Medical Engineering" specialty 163 "Biomedical Engineering" is carried out for entrants who have obtained the first (Bachelor's) level of higher education in the educational program specialty 163 "Biomedical Engineering" and related specialties.

The comprehensive professional exam aims to assess the level of knowledge of entrants in the disciplines that are most important for the formation of professional competencies. The comprehensive professional exam is a written exam including the following disciplines: Mechanics (PO 10), Object-oriented Programming (PO 11), Analog and digital circuitry - 2. Digital circuitry (PO 13). The examination lasts for 2 academic hours (90 minutes) - without a break. The examination task contains three questions – one for each discipline.

MAIN EXPLANATION

Content of educational material required for examination

Discipline 1. **Object-oriented programming**

1.1. Differences between procedural, object and object-oriented programming.

1.2. Object-oriented programming, design and analysis. Basic concepts and definitions.

1.3. Basic concepts and definitions of object-oriented programming: the concept of class and object, the relationship between class and its objects in the program.

1.4. Object-oriented programming style paradigm: inheritance, polymorphism, encapsulation. Definitions and explanations with examples.

1.5. What is a preprocessor? What is a compiler? What are preprocessor directives? What is their purpose?

1.6. Features of syntax for realization of linear structures. Branching, selection and cycles.

1.7. How to declare an array? Describe the basic operations of array processing.

1.8. Describe the purpose of the functions and the features of their declaration. Features of returning and using the value of functions.

1.9. What is recursion? Give examples of recursive algorithms.

1.10. Definition and declaration of global objects and functions.

1.11. C ++ class description format, example code with explanation. Purpose and differences between the forms class, struct, union.

1.12. Class fields, their purpose. The difference between class fields and variables in the program code, the principles of defining and initializing fields.

1.13. Class methods, their purpose.

1.14. Defining and working with class objects, examples. The lifetime of objects.

1.15. Format of definition and rules for objects and array of objects use. Code examples to explain the rules for initializing static and dynamic object arrays.

1.16. The concept of encapsulation. Class member access status, public, private, protected access specifiers.

1.17. The concept of encapsulation. Methods for setting and obtaining class field data, features of their definition in the program code. Give examples of program code using set/get methods with explanations.

1.18. Class member access operations. Determine the mechanism of transition to the use of point operations when working with pointers. Pointer this and its use (the most common situations, relevant examples).

1.19. Class constructor and its purpose. Format and rules for using default constructors and parameter constructors. Initialization list.

1.20. Class destructor and its purpose. Cases of implicit calls for destructors.

1.21. Purpose and rules of using constant class methods. Constant objects, the specifics of using the mutable specifier.

1.22. Static class members, access to static class members. Memory allocation when working with classes, specifics of memory allocation for fields and for class methods, static fields and methods.

1.23. Format of declaration, purpose and rules of how to use friendly functions and classes. Relevant examples of program code with explanations.

1.24. The concept of inheritance, general form. Hierarchy of classes, base class and descendant classes. Constructors and destructors in inheritance.

1.25. Overloading operations, two ways to identify overloaded operators.

1.26. Operations that cannot be overloaded are the reasons. Operations that cannot be overloaded with global friendly functions, reasons.

1.27. The principle of polymorphism. The main forms of the polymorphism principle in the C ++ programming language, relevant examples of program code with explanations.

1.28. The concept of exceptional situation and its processing. Ways to handle errors in software applications. The syntax for generating and handling exceptions in the C ++ programming language.

1.29. Exceptional handling mechanism in C ++ programming language. Classes of exceptions. Pass the exception to the catch block by value and by link.

1.30. Standard types of exceptions from the std library. Assigned functions terminate (), unexpected (), abort () during exception handling. Give an example of a code that can be used to display a text message with the line number during which an exception occurred and the name of the file that contains that line.

1.31. Classes of standard flows, their hierarchy and purpose. Features of overloading read/write operations to the stream.

Discipline 2. **Analog and digital circuitry - 2. Digital circuitry**

2.1. Algebraic logic. Standard forms of logical functions. Minimization of logical functions.

2.2. Diode switches. Logic circuits on diodes. Switches on bipolar transistors.

2.3. Switches on Schottky transistor. Switches on unipolar transistors.

2.4. Diode-transistor (DTL) logic elements (LE). Basic LE AND-NO. DTL-elements OR-NO, AND-OR-NO. DTLS element. Typical parameters of DTL.

2.5. Transistor-transistor LE (TTL). Basic LE AND-NO. TTL-elements OR-NO, AND-OR-NO. LE with a free collector. LE with three states of output. Typical parameters of TTL and TTLS.

2.6. LE on MISFET and CMOS transistors. LE AND-NO, OR-NO. Implementation of CDNF and CCNF on CMOS transistors. Buffer amplifiers. Protection of CMOS LE from static electricity. Conjugation of CMOS elements with TTL. Typical parameters of CMOS elements.

2.7. PC synthesis. Examples of PC implementation based on LE.

2.8. Encoders and decoders. Unitary code. Priority encoders. Decoders - linear, pyramidal, matrix. Minimize incomplete decoders. Synthesis of PC based on the decoder-encoder system.

2.9. Multiplexers and demultiplexers. Synthesis of multiplexers and demultiplexers. Gating, use of decoders in gating. Analog multiplexer-demultiplexer.

2.10. Combination shift devices on multiplexers. Implementation of logic functions on multiplexers.

2.11. Half-adders. Full adders. Subtractors. Subtractor adders. Binary-decimal adder.

2.12. Multi-bit adders with serial transfer. Multi-bit adders with accelerated transfer. Combination multipliers.

2.13. Digital comparators - single-bit and multi-bit. Binary minus comparators. Sectioned multi-bit comparators.

2.14. RS-triggers asynchronous and transparent synchronous. Varieties of RS-triggers (R-, S-, E-triggers). RS-triggers such as “latch” and MS.

2.15. D-flip-flops asynchronous and transparent synchronous. D-flip-flops and MS. D-flip-flops in counter mode.

2.16. Universal JK-triggers such as "latches" and MS. Basic parameters of triggers.

2.17. Parallel registers. Shear registers. Reversible shift registers. Ring registers. Register - "Johnson's counter".

2.18. Asynchronous and synchronous counters. Reversible counters. Frequency dividers.

2.19. Binary-decimal counters. Counters with a controlled conversion factor.

2.20. Synthesis of counters with an arbitrary table of transitions. Polynomial counters.

2.21. Pulse front detectors. Pulse expanders. Binding pulses to a constant level. Trigger pulse generators.

2.22. Timers. Self-oscillating pulse generators on logic elements.

2.23. Single vibrators and self-oscillating pulse generators on operational amplifiers. Shapers and generators of linear alternating current and voltage.

2.24. Digital-to-analog converter based on analog adder, resistive structure R-2R and current switches.

2.25. Analog-to-digital balancing converter. Parallel analog-to-digital converts.

Discipline 3. **Mechanics**

Introduction to the basics of biomechanics

3.1. General overview of the human body. Standard human body model. Allometric rules. Mechanical properties and their features for biological tissues and fluids.

3.2. Physical aspects of strength and fracture of materials Mechanical testing of materials. Anisotropy of mechanical properties of biological materials.

3.3. Basics of rheology. Combined rheological models of elastic-viscous, viscoelastic and viscoplastic materials. Rheological behavior of liquids.

Biomechanics of the human musculoskeletal system.

3.4. Muscle activity as a necessary condition for human life. Biomechanical properties of muscles Muscle response to stimuli. Molecular mechanism of contraction. Sliding filament theory. Skeletal muscle models. Structure and mechanical properties of tendons. Auxiliary muscle apparatus.

Biomechanics of motion qualities.

3.5. Mechanisms of development of motor qualities. Muscle modes. Dependence of strength on the rate of muscle contraction. Hill equation. Factors that determine the mechanical properties of muscles. Weber and Bernoulli principles. Muscle coordination. Strength qualities. Methods of development (training) of muscle strength. Physical performance. Development of agility, endurance and flexibility.

Biomechanics of movements (locomotion).

3.6. Biomechanical analysis of human motor activity. Methods of modeling the human body. Inertial and somatic reference systems. The general center of mass. Biokinematic and biodynamic characteristics of movements. Equilibrium conditions and indicators of body stability. Research of kinematics of movements. Coordinate transformation method. Basics of sports biomechanics. Instrumental methods of research of human motor actions.

3.7. Biodynamics of walking. External forces and reaction forces of support. Pendulum model of walking. Biodynamics and phases of running. Energy metabolism when walking and running. Biodynamics of the jump and its stages. Biomechanics of different sports.

Biomechanics of hemodynamics.

3.8. Basics of hemodynamics. The law of conservation of mass. The law of conservation of momentum (Bernoulli equation). Newton's law of viscous friction. The movement of a viscous fluid in the tube. Distribution of internal friction stress in the fluid flow. Flow modes. Poiseuille's equation. Hydrodynamic resistance. Viscosity measurement. Newtonian and non-Newtonian fluids. Curves of currents.

3.9. Rheological properties of blood. Dependence of viscosity on hematocrit. The Fareus and Fareus-Lindqvist effects. Kesson model. Manifestations of thixotropy. Erythrocyte as a viscoelastic body. Mechanical properties of blood vessels. Laplace's law. Lame equation. Features of blood flow in the branching of blood vessels. Mechanical properties of heart structures. Work and power of the heart. Pulse wave propagation in arteries, Moens-Korteweg equation. Models of the hemodynamics in the cardiovascular system.

Biomechanics of the human digestive and musculoskeletal systems.

3.10. Purpose, structure and main functions of the digestive system. Peristaltic mechanism of transport and mixing. Mechanical phenomena in the digestive tract. The main functions of the stomach. Stomach model.

3.11. Biomechanics of the musculoskeletal system. Lever devise of the musculoskeletal system. Skeleton system. Mechanical properties of bone tissue. Synovial joints and their classification. Mechanical properties of joints. Friction and lubrication in the joints. Posture and geometry of the masses. Principles of diagnosis and correction of scoliosis. Means and methods of biomechanical influence on the position of the head and spine.

3.12. Biokinematic chains and biokinematic pairs. Degrees of freedom of biokinematic pairs. Kinematic diagram of the human musculoskeletal system. Dynamics of the musculoskeletal system. Anthropometric and mass inertial characteristics of the human body. Approaches to the rehabilitation of mechanical functions of the human musculoskeletal system.

Biomechanics of human sensory reception.

3.13. The role of analyzers in the implementation of motor response. Classification of analyzers. Mechanical properties of eye structures. Intraocular pressure and methods of its measurement. Biomechanics of hearing and vestibular system. Mechanical properties of the ear and its structures. Biomechanics of the membrane of the otolith apparatus. The movement of endolymph and bought in semicircular canals.

CONCLUDING REMARKS

During the comprehensive professional exam, an entrant receives the examination task comprising three questions of equal complexity (from each discipline). The final mark is defined as the sum of the points scored for the answers to each of the three questions of the examination task. Evaluation criteria are applied to task verification based on the completeness, logic and correctness of the disclosure of the question. The maximum weight score is 100 points: the maximum number of points for the first and second questions – 33 and for the third – 34.

Evaluation criteria for the first and second questions with points:

- complete answer with explanations (not less than 90% of the required information), does not contain off-topic information - 33… 31 points;
- complete answer with minor inaccuracies (not less than 80% of the required information), does not contain off-topic information - 30… 27 points;
- in principle correct answer with minor inaccuracies (not less than 70% of the required information), some information is off-topic - 26… 23 points;
- complete answer with inaccuracies (not less than 60% of the required information) – 22…20 points;
- incomplete answer with no major inaccuracies (at least 50% of the required information), including errors – 19…17 points;
- incomplete answer with major errors and (or) major inaccuracies (less than 50% of the required information) – 16… 1 points;
- no answer provided – 0 points.

Evaluation criteria for the third question with points:

- complete answer with explanations (not less than 90% of the required information), does not contain off-topic information - 34… 32 points;
- complete answer with minor inaccuracies (not less than 80% of the required information), does not contain off-topic information - 31… 27 points;
- in principle correct answer with minor inaccuracies (not less than 70% of the required information), some information is off-topic - 26… 23 points;

- complete answer with inaccuracies (not less than 60% of the required information) – 22…20 points;
- incomplete answer with no major inaccuracies (at least 50% of the required information), including errors – 19…17 points;
- incomplete answer with major errors and (or) major inaccuracies (less than 50% of the required information) – 16… 1 points;
- no answer provided – 0 points.

Given that the admission exam for a foreign language at a master's level follows the format of external evaluation according to "Admission rules to Igor Sikorsky KPI" when calculating the admission scores it is necessary to use an evaluation scale from 100…200 points (similar to that in the complex admission exam). For this reason, it is necessary to convert the scores into a 200-point scale. The conversion table is given below.

Conversion table for score rates (SR) 60…100 points to complex admission exam (CAE) 100…200 points)

Mark SR Mark CAE Mark SR Mark CAE Mark SR Mark CAE Mark SR Mark CAE

Таблиця відповідності оцінок РСО (60…100 балів) оцінкам ЄВІ (100…200 балів)

Оцінка РСО	Оцінка ЄВІ	Оцінка РСО	Оцінка ЄВІ	Оцінка РСО	Оцінка ЄВІ	Оцінка РСО	Оцінка ЄВІ
60	100,0	70	125,0	80	150,0	90	175,0
61	102,5	71	127,5	81	152,5	91	177,5
62	105,0	72	130,0	82	155,0	92	180,0
63	107,5	73	132,5	83	157,5	93	182,5
64	110,0	74	135,0	84	160,0	94	185,0
65	112,5	75	137,5	85	162,5	95	187,5
66	115,0	76	140,0	86	165,0	96	190,0
67	117,5	77	142,5	87	167,5	97	192,5
68	120,0	78	145,0	88	170,0	98	195,0
69	122,5	79	147,5	89	172,5	99	197,5
						100	200,0

During the exam, it is allowed to use a calculator, basic formulas and a table of digital codes. Supporting materials are provided by the examiner.

A typical example of the comprehensive professional exam task

NATIONAL TECHNICAL UNIVERSITY OF UKRAINE

«IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE»

second (Master's) level of higher education

Specialization	163 Biomedical engineering
Educational professional program	Medical engineering
Exam	Comprehensive professional exam

EXAMINATION TASK № 1

1. Object-oriented programming, design and analysis. Basic concepts and definitions.

2. Algebraic logic. Standard forms of logical functions. Minimization of logical functions.

3. The r $\text{kg} \cdot \text{m}^2$ inertia for the thigh relative to the axis passing through the hip joint $I = 0,37\ кг \cdot м^2$. Determine the moment of inertia of the thigh relative to an axis that is parallel to the given one and passes through the center of mass of the thigh. The distance between the axes is 0.17 m, the mass of the thigh is 7.15 kg.

Materials and resources

Object-oriented programming

Basic literature

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2. Путятін Є.П. Основи програмування мовою С+ + : навчальний посібник / Є.П. Путятін, В.А. Любченко, О.А. Кобилін, Д.О. Руденко, Д.С.Пелешенко. - Харків : С.Ф. Коряк, 2018. - 282 с.

3. Гришанович Т. О. Основи об'єктно-орієнтованого програмування : навч. Посіб. / Т.О.Гришанович; СНУ ім. Лесі Українки. - Харків : ФОП Панов А.М., 2020. - 104 с.

4. Матвієнко М. П. Теорія алгоритмів. Навчальний посібник. — К.: Видавництво Ліра-К, 2017. — 340 с.

Additional literature

5. Алгоритмізація та програмування мовою високого рівня С ++ : комп'ютерний практикум: навчальний посібник для студентів, які навчаються за спеціальністю 122 "Комп'ютерні науки та інформаційні технології", спеціалізацією "Інформаційні технології в біології та медицині" / С.М. Алхімова ; Міністерство освіти і науки України, Національний технічний університет України "Київський політехнічний інститут імені Ігоря Сікорського". - КПІ ім. Ігоря Сікорського, 2018. - 154 с.

6. Шилдт, Герберт, C++ : базовый курс / Герберт Шилдт ; перевод с английского Н.М. Ручко. - Київ : Діалектика, 2020. - 620 с.

7. Іванов Є.О., Ліндер Я.М., Жереб К.А. Основи мови програмування С++: навчальний посібник. – К.: Логос. 2020. – 90 с.

Digital circuitry

Basic literature

1. Цифрова схемотехніка. Конспект лекцій до вивчення кредитного модуля дисципліни «Цифрова схемотехніка» [Електронний ресурс] : навчальний посібник для студентів, які навчаються за спеціальністю 163 – Біомедична інженерія, спеціалізацією «Клінічна інженерія» / КПІ ім. Ігоря Сікорського ; уклад.: В. І. Зубчук, М. Делавар-Касмаі. – Електронні текстові данні (1 файл 2,61 Мбайт). – Київ : КПІ ім. Ігоря Сікорського», 2019. – 184 с.

2. Цифрова схемотехніка [Електронний ресурс] : практикум з дисципліни для студентів спеціальностей 6.051402 - «Біомедична інженерія» та 6.051003 «Приладобудування» / В. І. Зубчук, Н. В. Захарчук ; КПІ ім. Ігоря Сікорського. – Електронні текстові данні (1 файл: 5,07 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2017. – 194 с.

3. Рябенький В.М. Цифрова схемотехніка : навчальний посібник для студентів вищих навчальних закладів / В.М. Рябенький, В.Я. Жуйков, В.Д. Гулий. - Львів : Новий Світ-2000, 2019. - 735 ст.

Additional literature

4. Борисенко О.А. Цифрова схемотехніка : підручник / О.А. Борисенко ; Міністерство освіти і науки України, Сумський державний університет. - Суми : Університетська книга, 2016. - 199 с.

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Basic literature

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2. Тарасова, Л. Д. Біомедична механіка. Збірник завдань до домашніх контрольних робіт [Електронний ресурс] : навч. посіб. для здобувачів ступеня бакалавра за освітньою програмою «Медична інженерія» спеціальності 163 «Біомедична інженерія» / Л. Д. Тарасова ; КПІ ім. Ігоря Сікорського. – Електронні текстові дані (1 файл: 1,36 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2020. – 45 с.

3. Конспект лекцій з дисципліни «Біомедична механіка» для здобувачів освітнього рівня «бакалавр» спеціальності 163 – Біомедична інженерія, освітня програма «Біомедична інженерія» / уклад. Д. Х. Штофель. Вінниця : ВНТУ, 2020. - 83 с.

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PROGRAM DEVELOPERS

Vladislav SHLYKOV, D.Sci., Assoc Prof. _____

Viktor ZUBCHUK, Ph.D., Assoc Prof. _____

Larisa TARASOVA, Ph.D., Assoc Prof. _____