MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
SIMON KUZNETS KHARKIV NATIONAL UNIVERSITY OF ECONOMICS

"APPROVED"
Vice-Rector for Educational and Methodical Work

Karina NEMASHKALO

DISCRETE MATHEMATICS
syllabus of the academic discipline

Training direction	**12 Information technologies**
Speciality	**121 Software engineering**
Academic degree	**first (bachelor)**
Academic program	**Software engineering**

Status of the academic discipline	**Compulsory**
Language of teaching, training and assessment	**English**

Chief of the department of higher mathematics, economical and mathematical methods — **Lyudmyla MALYARETS**

Kharkiv
2023

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ХАРКІВСЬКИЙ НАЦІОНАЛЬНИЙ ЕКОНОМІЧНИЙ УНІВЕРСИТЕТ
ІМЕНІ СЕМЕНА КУЗНЕЦЯ

"ЗАТВЕРДЖУЮ"
Проректор з навчально-методичної роботи

Карина НЕМАШКАЛО

ДИСКРЕТНА МАТЕМАТИКА
робоча програма навчальної дисципліни

Галузь знань	**12 Інформаційні технології**
Спеціальність	**121 Інженерія програмного забезпечення**
Освітній рівень	**перший (бакалаврський)**
Освітня програма	**Інженерія програмного забезпечення**

Статус дисципліни	***обов'язкова***
Мова викладання, навчання та оцінювання	***англійська***

Завідувач кафедри вищої математики та економіко-математичних методів **Людмила МАЛЯРЕЦЬ**

Харків
2023

APPROVED

at the meeting of the department of higher mathematics and economic mathematical methods
Protocol № 7 dated 21.12.2022

Compiled by:
Ie. Misiura, PhD, Associate professor of the department of higher mathematics and economic mathematical methods;
T. Denysova, PhD, Associate professor of the department of higher mathematics and economic mathematical methods

Sheet of renewal and re-approval of the academic discipline syllabus

Academic year	Date of the department meeting – the developer of syllabus of the academic discipline	Protocol number	Signature of chief of the department

The annotation of the academic discipline

The task of the economic and mathematical modelling is construction of models of economic objects and processes in order to describe, optimize, analyze, forecast, provide analytical support for these objects and processes when making decision at all levels of management. Thus, modelling is a fundamental basis of the methodology of management of the economy. Economic and mathematical models are constructed with the help of mathematical methods. Discrete mathematics are tools for learning and investigation of economic systems of different complexity. They form a fundamental basis for solving real analytical problems in different fields of activity of management subjects.

The fundamental basis in the mathematical preparation of economists and managers is the academic discipline "Discrete mathematics" which is a compulsory discipline of the natural scientific series and a component of the structural logical scheme which is provided for the educational professional program of Bachelor's (first) degree students of speciality 121 “Software engineering”.

The basic problems of teaching the academic discipline is giving students knowledge of the basic parts of Discrete mathematics; raising the level of the fundamental mathematical training of students with intensification of its applied direction, mastering the fundamentals of Discrete mathematics and application of this knowledge to the economic investigations for solving economic problems, forming skills in the application of elements of Discrete mathematics to investigations where mathematical methods (the mathematical programming and econometrics) are applied as an instrument of investigation and solving optimization economic problems for forming models of economic processes and developments, acquiring the necessary theoretical and practical knowledge for solving specific problems which are set in the process of forming and a construction of economic and mathematical models, and obtaining the required mathematical knowledge for the study of other disciplines.

The main purpose of teaching is to form future specialists' basic mathematical knowledge for solving theoretical and practical problems in professional activity of a competent specialist in any sphere of his activity, skills in analytical thinking and skills in using mathematical knowledge for formation of real processes and developments, and for solving economic problems.

The characteristics of the academic discipline:

Academic year	**1st**
Term	**2nd**
Number of credits	**5**
Form of the final control	**test**

Structural and logical scheme of studying the academic discipline:

Previous academic disciplines	Next academic disciplines
Higher mathematics	Course project: Object-oriented programming

Competences and result of mastering the academic discipline

General competences (GC) / Professional competences (PC)	Learning outcomes (LO)
GC01 (*3K01). An ability to abstract thinking, analysis and synthesis GC02 (3K02). An ability to use knowledge in practical situations	LO05 (*PH05). Know and use the corresponding mathematical concepts, methods of domain, system and object-oriented analysis and mathematical modeling for software development.

PC02 (СК02). An ability to participate in the design of software, including modeling (formal description) of its structure, a behavior and functioning processes. PC02 (СК03). An ability to develop architectures, modules and components of software systems. PC08 (СК08). An ability to use fundamental and interdisciplinary knowledge to successfully solve software engineering tasks PC14 (СК14). An ability to algorithmic and logical thinking	LO05 (*РН05). Know and use the corresponding mathematical concepts, methods of domain, system and object-oriented analysis and mathematical modeling for software development.

* ЗК – загальні компетентності, СК – спеціальні (фахові) компетентності,
РН – результати навчання

The syllabus of the academic discipline
The themes of lectures

Content module 1. *Set theory and combinatorial analysis. Graph theory*

Theme 1. Set theory and relations

1.1. Sets: definition of basic concepts, operations on sets. The purpose,an object, a subject and basic tasks of the educational discipline, its role in the development of the fundamentals of the theory of systems. Initial information related to the concept of "set": an element, an empty set, an equality of sets, a subset, an universe. Ways to create sets. Operation on sets: an union, an intersection, a difference, a complement. Euler-Venn' diagrams. Splitting sets.

1.2. Types of sets. Algebra of sets.

Biection. Equivalent sets. Capacity of sets. Finite and infinite, countable and uncountable sets. Continuous and discrete numeric sets. Closed set. Algebra of sets: definitions, basic laws, the principle of duality. Tuples. Direct (Cartesian) product of sets.

1.3. Binary Relations (BR).

BR: basic definitions, operations on BR. Geometric and matrix representation of BR. Basic characteristics (properties) of BR: reflexivity, antireflexivity, symmetry, antisymmetry, asymmetry, transitivity. Basic types of BR: equivalence, a relation of order, domination, tolerance. Using BR in information systems. Functional BR: definitions, types depending on the domain of existence and the region of values. Functions, functionals, operators. Functional composition, injective, bijective, inverse functions, bounded functions, their properties

Theme 2. Combinatorial analysis (CA)

CA: subject, basic problems, basic rules (product, sum, inclusion and exclusion (the sieve method). Basic combinatorial configurations (permutations, replacements, combinations) without repetitions and with repetitions: definitions, formulas for counting their quantity. Scheme "balloons and balls" (boxes and objects) for interpretation (simulation) of combinatorial configurations. General recommendations for solving problems for finding the quantity of basic combinatorial configurations. Combinatorial problems of an enumeration and a list. Recurrence ratios. Enumerators (generating functions) and denumerators. The problem of the partition of natural numbers.

Theme 3. Graph Theory

3.1. Unoriented graphs.

Types of graphs. Unoriented graphs: basic concepts, methods of assignment. Subgraph, path, chain, cycle. Finding chains of the smallest length. A connectivity graphs, trees and forest on the graphs. A construction of an economic tree. Analysis of special features of tree-like graphs.

3.2. Oriented graphs.

Oriented graphs: basic concepts, methods of assignment. Path, contour. Grid charts (GC): basic definitions, construction rules. An solving optimization problems in GC (the problem of finding critical time and critical path).

3.3. Transport networks (TN).

TN: basic definitions, finding a complete flow. Cuttings on TN. Maximal flows and minimal cut theorem. The problem of finding the maximum flow on TN (Ford-Fulkerson algorithm).

Content module 2. *Mathematical logic. Elements of the theory of finite automata*

Theme 4. Algebra of statements. Logical formulas

4.1. Algebra of expressions.

Expression: basic definitions, logical operations. Algebra of expressions, the laws of algebra of logic. Isomorphic algebras, Boolean algebras. Areas of a practical application of a mathematical logic.

4.2. Logical formulas.

Logical formulas: definition, classification, a principle of duality. The problem of solvability: the statement and ways of solving. Disjunctive and conjunctive normal forms (DNF, KNF): definitions, a construction. Perfect DNF, KNF: definitions, a construction based on known DNF and KNF. Formulas for the expansion of logical formulas and their application to the construction of normal forms.

Theme 5. Boolean functions (BF)

5.1. BF: basic concepts, domain of existence, methods of assignment, normal forms. Canonical minimization of the BF: problem statement, methods of minimization (analytical, tabular, graphic).

5.2. An application of the BF to the analysis and synthesis of contact schemes.

Contacts: definitions, types, operations on contacts. Algebra of contact schemes. Problems of analysis and synthesis of contact schemes: statement, algorithms of solving.

5.3. An application of the BF to the analysis and synthesis of logic schemes.

Logical elements: types, a schematic image. Incoming, outgoing, internal variables. Logical schemes. Problems of analysis and synthesis of logical schemes: a statement, algorithms of solving.

Theme 6. Predicates and quantifiers

Free variables. Predicates: examples, basic definitions, methods of assignment. Predicates' operations. Identically true and equivalent predicates. Quantifiers of an universality and an existence: definitions, properties. Entries of statements in the language of the predicate logic. Predicate Formulas

Theme 7. Elements of the theory of finite automata

7.1. Finite automatics: basic definitions, a classification.

Cybernetic systems: definition of basic concepts. Finite automatics as keyless systems: basic definitions, methods of assignment, properties, classification.

7.2. Analysis, synthesis and minimization of finite automata.

Problems of analysis, synthesis and minimization of finite automata: problems' statement and their solving.

Methods of study and teaching

To intensify the process of teaching the academic discipline Discrete mathematics the following educational technologies are applied problem lectures, mini-lectures, work in small groups, brainstorms, computer simulation (games).

The basic difference of active and interactive methods of education from traditional ones is not only defined by the methods and techniques of teaching, but also by a high effectivity of the educational process, which reveals itself in: the high motivation of students; consolidation of theoretical knowledge in practice; improvement of students' consciousness; forming the ability to make an independent decision; forming the ability to approve collective decisions; forming the ability for social integration; getting the skills in resolving conflicts; development of the ability to reach

compromises.

Problem lectures are directed at the development of students' logical thinking. The theme is confined to two or three key issues, students' attention is concentrated on the material which has not been represented in textbooks, the experience of foreign educational universities is used with handing out printed materials to students during the lecture and drawing basic conclusions as to the issues considered. In the course of lectures students are asked questions for independent reflection which a lecturer answers himself, without waiting for students' answers. This kind of system makes students concentrate and begin to actively think in search of a correct answer (*themes:* 1, 3, 7).

Mini-lectures provide for the delivery the educational material during a short-length segment of time and they are charactirized by a significant content, complexity of logical constructions, forms, proofs and generalizations. They are conducted, as a rule, as a part of a study-investigation. Mini-lectures differ from full-size lectures by a shoter duration. Usually, they last no more than 10 – 15 minutes and they are used in order to give briefly new information for all students. Mini lectures are often used as parts of a whole theme, which it is desirable to teach as a full-size lecture in order to avoid the audience's getting tired. Then the information is given by turn as several particular fragments, between them other forms and methods of study are used (*theme:* 3).

Brainstorming is a method of solving urgent tasks, its core lies in expressing as many ideas as possible in a short period of time, discussing and selecting them (*themes:* 2, 3).

A computer simulation (game) is an education method, which is based on the use of a spesific computer program in order to get visual modelling of a process. Students can change the parameters and data, decisions and analyze the results of such decisions. The purpose of using this method is the development of systematic thinking of students, their ability to plan, form skills to identify and analyze problems, compare and estimate alternatives, make optimal decisions and work under the condition of a limited time (*theme:* 1).

Work in small groups gives an opportunity to structure practical studies in the form and content, gives a possibility for each student's partaking in the work on the theme under study, stimulates forming personal qualities and experience of social communication (*themes:* 4, 5).

Presentations are speeches to students which are used for presenting certain achievements, group work results, reports of individual task fulfillment, instruction, demonstration of new goods and services (*themes:* 1 – 7).

Seminar-discussions provide for exchange of thoughts and ideas of students on the given theme and develop thinking, help to form ideas and beliefs, produce skills in formulating thoughts and expressing them, teach to assess other people's proposals, critically come to personal ideas time (*theme:* 3).

The order of assessment of studying results

The system of assessment of competences which were formulated for a student during the learning of the academic discipline, takes into consideration the forms of studies which according to the syllabus of the academic discipline provide lectures, practical studies, laboratory works, fulfillment of students' independent work.

The assessment of the formed competences of students is carried out on the accumulative 100-point system. Control ways include:

current control which is carried out within a term during lectures, practical studies and laboratory works and it is assessed as a sum of accumulative points (the maximum equals 100 points; the minimum which makes it possible for a student to pass a test, equals 60 points);

module control which is carried out in the form of a colloquium with taking into account the current control according to a corresponding thematic module, provides an integral assessment of student's results after learning the material of a logically completed part of the discipline (or a content module);

final/term control, which is carried out as a differential test, which is an assessment of a level of students' final mastery of the theoretical and practical material of the educational discipline. A test is a total sum of accumulative points obtaining as a result of a current control.

Current control on the given academic discipline is carried out in the following forms: homework; defence of laboratory works; a written test; an independent creative work, a colloquium.

The total number of points is 100, which are distributed as lectures (including 2 colloquiums by 10 points (20 points)), one independent creative task (8 points), practical studies including 3 written tests by 11 points (33 points) and 7 homework by 3 points (21 points), laboratory studies including 9 laboratory works by 2 points (18 points).

Assessment of student's knowledge during practical studies and carrying out laboratory works is conducted on the accumulative system according to the following criteria: understanding, the degree of the mastery of the theory and methodology of problems which are considered; the degree of the mastery of the factual material of the academic discipline; familiarizing with the recommended literary sources and modern literature on the questions which are considered; the ability to connect theory and practice in the consideration of particular examples, solving problems, carrying out laboratory works, carrying out calculations in the process of doing homework and tasks which are considered in class; the logic, structure, style of presenting the material in written works and in oral answers in class, the ability to ground one's position, carry out generalization of the information and draw conclusions.

The general criteria for the assessment of ***independent work*** of students are profound and deep of knowledge, the level of thinking, skills in systematization knowledge on particular themes, skills in drawing conclusions, attainments and techniques of carrying out practical tasks, the ability to find necessary information, carry out its classification and processing, self-realization in practical and laboratory studies.

The criteria for assessment of independent creative work and independent tests are: the ability to carry out a critical and an independent estimation of the defined problem questions; skills in the explanation of alternative views and availability of a students' own point of view, position on the defined problem question; using the analytical approach; the quality and accuracy of expressing the thought; the logic, structure and explanation of conclusions about a particular problem; independence of carrying out of the work; grammatical correctness of the presentation of the material; using the methods of comparison, generalization of the concepts and facts; the design of the work; the quality of presentation.

Independent work is a scheduled educational and scientific work which is carried out on a lecture task under the methodical and scientific guidance of a lecturer, it is a specific form of the educational activity, its main objective is forming independence of a person.

The educational time, which is intended for students' independent work of the day-time form of education, is defined according to the educational plan and makes 60 % out of the total educational time for learning the discipline.

During independent work a student becomes an active participant in the educational process, learns to master consciously theoretical and practical knowledge, orientates easily in the information space, has to take responsibility for the quality of his own professional training.

The necessary element of successful mastery of the material of the academic discipline is the students' independent work (SIW) with specifical literature of the mathematical and economic direction.

SIW includes: processing of the lecture material of (a lecture as a form of education provides theoretical knowledge, besides being used for carrying out practical calculations); processing and learning the recommended literature, basic terms and concepts on the themes of the academic discipline; preparation for practical and laboratory studies; preparation for the defence of laboratory works; an advanced study of particular themes or questions of lectures; carrying out practical homework, solving computational competence oriented tasks on the given theme; choosing and consideration of literature sources on the given problem of the academic discipline; analytic consideration of scientific publications; self-control of students' knowledge by questions for self-diagnostics; carrying out independent work; carrying out independent creative work; preparation for tests and other forms of current control; preparation for module control (a colloquium); systematization of the studied material with the purpose of preparation for terminal exams on each module of the academic discipline.

A student can't be allowed to pass the test, if the number of points, obtained during the current

and module control according to the thematic module during the term, does not make 60 points. After the examination period the dean of the department gives a notice about sitting the failed test. In a given period the student adds the required points.

It should be assessed student's progress, if a sum of points, obtained as the total result of an assessment by all forms of a control, equals or exceeds 60.

The total result in points during the term is "*60 and more points mean passed*", "*59 and less points mean failed*" and it is entered into the "*Mark sheet*" on the academic discipline.

Rating-plan of the academic discipline

Theme	Forms and types of study		Forms of assessment	Maxi-mal point
1	**2**		**3**	**4**
Theme 1. Set theory and relations	***Class work***			
	Lecture	**Lecture 1. Set theory**		
		Lecture 2. Binary relations		
	Practical study	**Practical study 1. Set theory**		
		Practical study 2. Binary relations		
	Laboratory study	**Laboratory work 1. Set theory**	laboratory work	2
		Laboratory work 2. Binary relations	laboratory work	2
	Independent work			
	Questions and tasks to self-study	Search, choice and looking through literary sources on the theme. Learning the lecture material. Carrying out practical homework and a laboratory work	homework	3
Theme 2. Combinatorial analysis	***Class work***			
	Lecture	**Lecture 3. Combinatorial analysis**		
	Practical study	**Practical study 3. Combinatorial analysis**	written test	11
	Laboratory study	**Laboratory work 3. Combinatorial analysis**	laboratory work	2
	Independent work			
	Questions and tasks to self-study	Search, choice and looking through literary sources on the theme. Learning the lecture material. Carrying out practical homework and a laboratory work	homework	3
Theme 3. Graph theory	***Class work***			
	Lecture	**Lecture 4. Undirected graphs**		
		Lecture 5. Directed graphs		
		Lecture 6. Transport networks		
	Practical study	**Practical study 4. Undirected graphs**		
		Practical study 5. Directed graphs	written test	11
	Laboratory study	**Laboratory work 4. Undirected graphs**	laboratory work	2
		Laboratory work 5. Directed graphs	laboratory work	2
	Independent work			
	Questions and tasks to self-	Search, choice and looking through literary sources on the theme. Learning the lecture	homework	6

	study	material. Carrying out practical homework and a laboratory work		
Theme 4. Algebra of statements. Logical formulas	***Class work***			
	Lecture	**Lecture 7. Algebra of statements**	colloquium	10
	Lecture	**Lecture 8. Logical formulas**		
	Practical study	**Practical study 6. Algebra of statements. Logical formulas**		
	Laboratory study	**Laboratory work 6. Algebra of statements. Logical formulas**	laboratory work	2
	Independent work			
	Questions and tasks to self-study	Search, choice and looking through literary sources on the theme. Learning the lecture material. Carrying out practical homework and a laboratory work	homework	3
Theme 5. Boolean functions	***Class work***			
	Lecture	**Lecture 9. Boolean functions**		
		Lecture 10. Application of Boolean functions	independent creative task	**8**
	Practical study	**Practical study 7. Boolean functions**		
		Practical study 8. Application of Boolean functions		
	Laboratory study	**Laboratory work 7. Boolean functions**	laboratory work	2
		Laboratory work 8. Application of Boolean functions to the analysis and synthesis of contact schemes	laboratory work	2
		Laboratory work 9. Application of Boolean functions to the analysis and synthesis of contact schemes	laboratory work	2
	Independent work			
	Questions and tasks to self-study	Search, choice and looking through literary sources on the theme. Learning the lecture material. Carrying out practical homework and a laboratory work	homework	6
Theme 6. Predicates and quantifiers	***Class work***			
	Lecture	**Lecture 11. Predicates and quantifiers**		
	Practical study	**Practical study 9. Predicates and quantifiers**	written test	11
	Independent work			
	Questions and tasks to self-study	Search, choice and looking through literary sources on the theme. Learning the lecture material. Carrying out practical homework		
Theme 7. Elements of the theory of finite automata	***Class work***			
	Lecture	**Lecture 12. Elements of the theory of finite automata**	colloquium	10
	Independent work			
	Questions and tasks to self-study	Search, choice and looking through literary sources on the theme. Learning the lecture material.		

Recommended reading

Main

1. Дискретна математика [Електронне видання] : навчальний посібник / Т. В. Денисова, В. Ф. Сенчуков. – Харків : ХНЕУ ім. С. Кузнеця, 2019. – 288 с. – Режим доступу : http://www.repository.hneu.edu.ua/handle/123456789/22003

2. Дискретна математика. Методичні рекомендації до самостійної роботи з теми "Теорія графів" для студентів галузі знань 12 "Інформаційні технології" першого (бакалаврського) рівня [Електронний ресурс] / укл. Т. В. Денисова, В. Ф. Сенчуков; Харківський національний економічний університет ім. С. Кузнеця. – Електрон. текстові дан. (11,7 МБ). – Харків : ХНЕУ ім. С. Кузнеця, 2020. – 99 с. – Режим доступу : http://repository.hneu.edu.ua/handle/123456789/23848 .

3. Дискретна математика. Методичні рекомендації до самостійної роботи з теми "Теорія множин і відношень" для студентів галузі знань 12 "Інформаційні технології" першого (бакалаврського) рівня [Електронний ресурс] / уклад. Т. В. Денисова; Харківський національний економічний університет ім. С. Кузнеця. – Електрон. текстові дан. (10,7 МБ). – Харків : ХНЕУ ім. С. Кузнеця, 2021. – 79 с. – Режим доступу : http://repository.hneu.edu.ua/handle/123456789/26063 .

Additional

4. Сенчуков В. Ф. Мінімізація булевих функцій за номерами наборів значень аргументів / В. Ф. Сенчуков, Т. В. Денисова // Открытые информационные и компьютерные интегрированные технологии: науч. тр. – Харьков : Нац. аэрокосм. ун-т "ХАИ", 2019. – Вып. 83. – С. 156-167. – Режим доступу : http://nti.khai.edu/ojs/index.php/oikit/article/view/696/751

5. Сенчуков В. Ф. ν-мінімізація булевих функцій за матрицею відстаней та зведенням до задачі математичного програмування / В. Ф. Сенчуков, Т. В. Денисова // Відкриті інформаційні та комп'ютерні інтегровані технології: зб. наук. пр. – Харків : Нац. аерокосм. ун-т "ХАІ", 2020. – Вип. 88. – С. 123-133. doi: 10.32620/oikit.2020.88.10 – Режим доступу : http://nti.khai.edu/ojs/index.php/oikit/article/view/1254/1330.

6. Дискретна математика : методичні рекомендації до лабораторних робіт для студентів галузі знань 12 "Інформаційні технології" першого (бакалаврського) рівня / уклад. Т. В. Денисова, В. Ф. Сенчуков. – Харків : ХНЕУ ім. С. Кузнеця, 2018. – 114 с.

7. Нікольський Ю. В. Дискретна математика : підручник / Ю. В. Нікольський, В. В. Пасічник, Ю. М. Щербина ; за ред. В. В. Пасічника. – 5-те вид., випр. та допов. – Львів : Магнолія-2006, 2019. – 432 с.

8. Журавчак Л. М. Дискретна математика для програмістів : навч. посіб. / Л. М. Журавчак. – Львів : Видавництво Львівської політехніки, 2019. – 420 с.

9. Журавчак Л. М. Практикум з комп'ютерної дискретної математики : навч. посіб. / Л. М. Журавчак, Н. І. Мельникова, П. В. Сердюк ; Нац. ун-т "Львів. Політехніка". – Львів : Вид-во Львів. політехніки, 2020. – 313 с.

10. Дискретна математика для інформатиків : навч. посіб. / С. В. Бразинська, Т. М. Дубовик ; за ред. д-ра фіз.-мат. наук, проф. А. І. Косолапа ; ДВНЗ "Укр. держ. хім.-технол. ун-т". – Дніпро : ДВНЗ УДХТУ, 2018. – 150 с.

11. Борисенко О. А. Дискретна математика : підручник для студентів вищих навчальних закладів / О. А. Борисенко. – Суми : Університетська книга, 2019. – 255 с.

Internet Information Resources:

12. Дискретна математика : теорія множин і відношень, комбінаторика, числення висловлювань : навч. посіб. / Н. П. Тмєнова. – Київ : ВПЦ "Київський університет", 2018. – 103 с. – Режим доступу : http://pdf.lib.vntu.edu.ua/books/2020/Tmenova_2018_103.pdf .

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