DISCRETE MATHEMATICS FOR COMPUTER SCIENCE

Syllabus

Details of the educational component

Level of higher education	***First (Bachelor)***
Branch of knowledge	*12 Information Technologies*
Specialty	*121 Software Engineering*
Educational program	*Software Engineering of Multimedia and Information-Retrieval Systems*
Status of the educational component	*Normative*
Form of education	*Full-time*
A year of training	*1st year, Autumn semester*
The scope of the educational component	*Lectures: 36 academic hours, practice class: 18 academic hours, student's self-training: 78 academic hours.*
Semester control / control measures	*Exam, midterm test, quiz, calendar control*
Schedule of classes	*According to the schedule for the autumn semester of the current academic year (rozklad.kpi.ua)*
Language of instructions	*Ukrainian*
Information about head of the course / teachers	*Lectures: Ph.D., assoc. prof. Tetiana Likhouzova, likhouzova.tetiana@lll.kpi.ua* *Practice class: Ph.D., assoc. prof. Tetiana Likhouzova, likhouzova.tetiana@lll.kpi.ua*
Course location	Google classroom. Access is given to registered students.

Program of educational component

1. Description of the educational component, its purpose, subject of study and learning outcomes

The purpose *of studying the discipline (credit module) "Discrete mathematics for computer science" is the acquisition by students of key professional competencies, theoretical knowledge, and practical skills in discrete mathematics for further application in various areas of professional activity.*

The subject *of the discipline (credit module) "Discrete mathematics for computer science" is technologies, methods and means of describing objects.*

Studying the discipline (credit module) "Discrete mathematics for computer science" allows students to develop the ***competencies*** *necessary for solving complex specialized tasks and practical problems in the field of software engineering, which is characterized by the complexity and uncertainty of the conditions for the application of theories and methods of information technologies:*

GC 01 – Ability to abstract thinking, analysis and synthesis;

GC 02 – Ability to apply knowledge in practical situations.

GC 06 – Ability to search, process and analyze information from various sources.

The program results *of the discipline (credit module) "Discrete mathematics for computer science":*

PLO05 – To know and apply relevant mathematical concepts, domain methods, system and object-oriented analysis and mathematical modeling for software development;

PLO11 – To select initial data for design, guided by formal methods of describing requirements and modeling.

2. Pre-requisites and post-requisites of the educational component (place in the structural and logical scheme of training according to the relevant educational program)

The discipline (credit module) "Discrete mathematics for computer science" is basic. The theoretical knowledge and practical skills acquired during the study of the discipline " Discrete mathematics for computer science" are necessary for the study of the disciplines "Computer logic", "Algorithms and data structures", "Fundamentals of computer systems and networks" of the bachelor's training plan by specialty 121 Software engineering.

3. Content of the academic discipline

Discipline (credit module) "Discrete mathematics for computer science" involves the study of the following topics:

Topic 1. Sets

Topic 2. Relations

Topic 3. Algebraic structures

Topic 4. Boolean functions and transformations

Topic 5. Mathematical logic

Topic 6. Graph theory

Topic 7. Automatic machines

Modular control work

Exam

4. Educational materials and resources

Basic literature:

1. Educational and methodological materials for the educational component "Discrete mathematics for computer science".
Use to master practical skills in the discipline. The materials are in Google classroom. Access is granted to registered students.

2. Gary Haggard, John Schlipf, Sue Whitesides. Discrete mathematics for computer science. Thomson, 627 p. URL: https://www2.cs.uh.edu/~arjun/courses/ds/DiscMaths4CompSc.pdf

Educational content

5. Methods of mastering the educational component

No.	Type of training session	Description of the training session
		Topic 1. Sets
1	*Lecture 1. Sets*	*Methods of specifying sets. Elements of sets, methods of setting sets, finite and infinite sets, ordered sets. ([1] p.9, [2] p.35)*

		Basic concepts of set theory. Equality of sets, inclusion of sets, universal and empty sets, degree of a set. ([1] p.14, [2] p.35) *Geometric interpretation of sets. Venn diagrams, Euler circles.* *Operations on sets. Union, intersection, difference, addition. ([1] p.20, [2] p.37)* *Algebra of sets. Priority of operations, identities of algebra of sets, identity transformations of expressions. ([1] p.22, [2] p.37)*
2	*Practice class 1. Sets*	*Methods of specifying sets. Geometric interpretation of sets. Operations on sets. Algebra of sets. ([1] p.13, 21, [2] p.45, [9] p.4)*
3	*Practice class 2. Sets*	*Topic control work*
	Topic 2. Relations	
4	*Lecture 2. The concept of relation*	*The concept of relation. Setting relations. Cartesian product of sets, even relation, binary relation, ways of specifying relations. ([1] p.30, [2] p.194)* *Operations on relations. Inverse relation, the composition of relations, degree of relation, the section of relation, factor-set. ([1] p.37, [2] p.195)* *Properties of binary relations. Reflexivity, antireflexivity, symmetry, asymmetry, antisymmetry, transitivity, anti-transitivity. ([1] p.42, [2] p.196)*
5	*Practice class 3. The concept of relation*	*Setting relations. Operations on relations. Properties of binary relations. ([1] p.36, [2] p.204, [9] p.8)*
6	*Lecture 3. Types of relationships*	*Relations of equivalence, tolerance, order. Equivalence relations, equivalence classes, path in a graph, partial (non-strict) order, strict order, linear order, comparable and incomparable elements, tolerance relations. ([1] p.47, [2] p.198)* *Functional relations. Functional relationship, areas of definition and values, mapping, surjection, injection, bijection. ([1] p.54, [2] p.210)*
7	*Practice class 4. Types of relationships*	*Relations of equivalence, tolerance, order. ([1] p.46, [2] p.210, [9] p.15)* *Functional relations. ([1] p.60, [9] p.12)*
8	*Practice class 5. Relations*	*Topic control work*
	Topic 3. Algebraic structures	
9	*Lecture 4. Algebraic structures*	*Algebraic operations and their properties. Unary operation, binary operation, even operation, operand, infix entries, prefix, postfix, Cayley table, commutativity, associativity, distributivity, unit, inverse element, addition and multiplication operations by modulo. ([1] p.73, [7] p.67)* *Concept of algebraic structure. Algebraic structure, substructure, homomorphism, isomorphism. ([1] p.80, [4] p.189, [7] p.76)*

		The simplest algebraic structures. Semigroup, monoid, group, abelian group, rings and fields. ([1] p.85, [4] p.201, [7] p.77) *Grids. Upper and lower faces in a partially ordered set, lattice, full lattice, one and zero lattice. ([1] p.93, [7] p.96)*
Topic 4. Boolean functions and transformations		
10	*Lecture 5. Methods of specifying Boolean functions*	*Boolean variables and functions. Binary interpretations, significant and dummy variables. ([1] p.99, [2] p.235, [4] p.29)* *Methods of specifying Boolean functions. Truth table, two-element Boolean algebra, logic algebra, superposition of Boolean functions, priority of operations, equivalence of Boolean algebra formulas. ([1] p.102, [2] p.235, [4] p.35)*
11	*Practice class 6. Methods of specifying Boolean functions*	*Methods of specifying Boolean functions. Duality. Laws of Boolean algebra. ([1] p. 110, 114, 119, [2] p. 272)*
12	*Lecture 6. Laws of Boolean algebra*	*Duality. Dual and self-dual Boolean functions, principle of duality. ([1] p. 111)* *Laws of Boolean algebra. Laws of Boolean algebra. ([1] p.115, [2] p.240)* *Disjunctive and conjunctive expansions of Boolean functions. Decomposition theorems, elementary conjunction and disjunction, zero and one constituents, normal forms. ([1] p.120, [2] p.243)*
13	*Practice class 7. Laws of Boolean algebra*	*Disjunctive and conjunctive expansions of Boolean functions. Normal forms of the representation of Boolean functions. ([1] p.129, 137, [2] p.272, [9] p.30)*
14	*Lecture 7. Normal forms of the representation of Boolean functions*	*Normal forms of the representation of Boolean functions. Algorithms of transition from truth tables of Boolean functions to DDNF/DKNF and vice versa, algorithms of transition from an arbitrary formula to DCNF and DDNF. ([1] p.130, [2] p.243, [4] p.53)* *Minimization of Boolean functions. Basic concepts. Method of Carnot maps (Veach diagrams), partially defined functions. ([1] p.155, [2] p.257, [4] p.58) Minimization of functions by the Quine - McCluskey method. Minimization of functions by the Nelson method. Minimization of functions by the Poretsky-Blake method. ([1] p.165, [2] p.257)*
15	*Practice class 8. Normal forms of the representation of Boolean functions*	*Minimization of Boolean functions by the method of Carnot maps (Veach diagrams). Minimization of functions by the Poretsky-Blake method. ([1] p.176, [2] p.273, [9] p.34)* *Minimization of functions by the Quine-McCluskey method. Minimization of functions by the Nelson method. ([1] p.176, [2] p.273, [9] p.34)*
16	*Lecture 8. Zhegalkin Algebra*	*Zhegalkin Algebra. Linear functions. Structure and identities of Zhegalkin algebra, representation of disjunction and negation by Zhegalkin polynomial, linearity of Boolean functions. ([1] p.138, [2] p.267)*

		Functions that store zero and one. Monotonic functions. Order relations for interpretations, signs of monotonicity of a function. ([1] p.147)
17	*Practice class 9. Zhegalkin Algebra*	*Identities of the Zhegalkin algebra. Polina Zhegalkina. Linear functions. Functions that store zero and one. Monotonic functions. ([1] p.144)*
	Midterm Test	
	Topic 5. Mathematical logic	
18	*Lecture 9. Logic of statements*	*History and problems of mathematical logic. Historical background on the development of mathematical logic. Typical tasks. ([1] p.183, [2] p.9)* *The concept of the logic of statements. Statement, truth value, atom, logical connections, correctly constructed formula, interpretation of statement, priority and rank of operations, tautology, identically false formula, non-universal formula. ([1] p.185, [2] p.9)* *Deductive conclusions in the logic of statements. Logical consequence and its properties, axioms, proofs, rules of deductive conclusions. ([1] p.197, [2] p.26)* *Calculation of statements. Language, axioms and rules of inference, completeness and non-contradiction, rules of separation and substitution, deduction theorem and its consequence, proof by the method of the opposite. ([1] p.201, [2] p.15, [4] p.151)*
19	*Practice class 10. Logic of statements*	*Deductive conclusions in the logic of statements. Calculation of statements. ([1] p.200, [2] p.40)*
20	*Lecture 10. Logic of predicates*	*Logic of predicates. Predicate order, predicate scope, terms, subject variables and constants. ([1] p.207, [2] p.23, [4] p.158)* *Quantifiers. Quantifier of generality, quantifier of existence, bound and free variable, reduction of order of n-digit predicates. ([1] p.212, [2] p.25, [4] p.158)* *Formulas in predicate logic. Elementary formula, correctly constructed formulas, scope of quantifier, interpretation of predicate logic formulas, general and contradictory formulas, logical consequence. ([1] p.217, [2] p.23)* *Laws and identities in predicate logic. Substitution of a bound variable, commutative and distributive properties of quantifiers, de Morgan's law for quantifiers. ([1] p.220, [2] p.32)*
21	*Practice class 11. Logic of predicates*	*Logic of predicates. Quantifiers. Formulas in predicate logic. Laws and identities in predicate logic. ([1] p.211, 216, [2] p.30, [9] p.36)*
22	*Lecture 11. Normal forms*	*Normal forms and logical conclusion. Anticipated normal form, reduction algorithm to anticipatory normal form, rules for removing/inserting the generality/existence quantifier. ([1] p.223, [2] p.25)*

		Calculation of predicates. Structure of predicate calculation, separation and generalization rules, □ and □-input rules, renaming of free and bound variables. ([1] p.227, [2] p.34, [4] p.162) *Multi-valued logic. The emergence of multi-valued logics, the truth value of a statement, the alphabet of multi-valued logic, unary and binary functions, a complete system of functions of multi-valued logic. ([1] p.230)*
23	*Practice class 12.*	*Topic control work*
Topic 6. Graph theory		
24	*Lecture 12. Ways of specifying a graph*	*Basic terms. Historical background on the development of graph theory. Typical tasks. Undirected and directed graphs. Graph theory terms. Connectivity. ([1] p.239, [2] p.88)* *Ways of specifying a graph. List of edges. Incidence matrix. Adjacency matrix. Adjacency list. ([1] p.257, [2] p.95, [4] p.236)* *Operations on graphs. Union, intersection of graphs, complement and degree of a graph. ([1] p.253, [2] p.105, [4] p.241)*
25	*Lecture 13. Routes, chains and cycles*	*Euler and semi-Eulerian graphs. Routes, chains and cycles. Concept of Euler and semi-Eulerian graphs. Theorems on the necessary and sufficient conditions for the existence of an Euler cycle in a graph. ([1] p.246, [2] p.108, [4] p.250)* *Hamiltonian and semi-Hamiltonian graphs. The concept of Hamiltonian and semi-Hamiltonian graphs. Theorems on the necessary and sufficient conditions for the existence of a Hamiltonian cycle in a graph. ([1] p.304, [2] p.111, [4] p.252)* *Planarity of graphs. Isomorphism and homomorphism of graphs. The Pontryagin-Kuratovsky theorem. ([1] p.253, [2] p.124, [4] p.253)* *Graph coloring. The chromatic number of the graph. Theorems on the estimation of the chromatic number. The problem of four colors. Double count. Problems that can be solved by coloring graphs. ([1] p.260, [2] p.126, [4] p.249)*
26	*Practice class 13. Ways of specifying a graph. Routes, chains and cycles*	*Ways of specifying a graph. Operations on graphs. Isomorphism and homomorphism of graphs. ([1] p.256, 259, [2] p.138, [9] p.22)* *Euler and semi-Eulerian graphs. Hamiltonian and semi-Hamiltonian graphs. Planarity of graphs. Coloring. ([1] p.247, 268, [2] p.140)*
27	*Lecture 14. Trees. Skeletons of the graph*	*Trees. The concept and properties of a tree. Basic terms. Rooted and labeled trees. Oriented trees. Search in depth. Search width. ([1] p.269, [2] p.150, [4] p.249)* *Skeletons of the graph. Application. Algorithm for building the skeleton. Minimum weight. Kruskal's algorithm. ([1] p.269, [2] p.175, [4] p.248)*
28	*Practice class 14. Trees. Skeletons of the graph*	*Directed and binary trees. Search in the tree. Adding and removing nodes. Skeletons of the graph. ([1] p.285, [2] p.145)*

29	*Lecture 15. Shortest distances and paths in networks*	*Shortest distances and paths in networks. Dijkstra, Ford-Bellman algorithms for finding the shortest path between two vertices. Algorithms of Floyd and Danzig for finding the shortest paths between all vertices. ([1] p.292, [2] p.113, [4] p.277)*
30	*Lecture 16. Currents in networks*	*Study of sections and cycles in a graph. Fundamental matrices of sections and cycles. Application. Poincaré's theorem. ([1] p.286)* *Currents in networks. Sources and drains. Algorithms for calculating the maximum current in a network with one source and one drain and with many sources and drains. ([1] p. 322)*
31	*Practice class 15. Shortest distances and paths in networks. Currents in networks*	*Shortest distances and paths in networks. Study of sections and cycles in a graph. ([1] p.303, [2] p.146, [9] p.22) Currents in networks. ([1] p. 337)*
32	*Practice class 16.*	*Topic control work*
	Topic 7. Automatic machines	
33	*Lecture 17. Automatic machines*	*Basic concepts. Historical background on the development of the theory of automata. Typical tasks. ([1] p. 385)* *Finite automata. Methods of description. ([1] p.391, [2] p.285)* *Converters. Methods of description. Typical tasks. Moore and Miley automata ([1] p.399)* *Recognizers. Methods of description. Typical tasks. ([1] p. 385)* *Minimization of automata. Non-deterministic automata. Partial automata. Epsilon automata. Methods of description. Typical tasks. ([1] p.459, [2] p.314)*
34	*Lecture 18. Languages and grammars.*	*Languages and grammars. Algebraic operations with languages. Regular languages. Search engines. Formal grammars. Hierarchy of grammars. Chomsky's normal form. Normal Greibach form. Recognition of context-free languages. ([1] p.478, [2] p.314)*
35	*Practice class 17. Automatic machines*	*Moore and Miley automata. ([1] p.391, [2] p.285)*
36	*Practice class 18. Automatic machines*	*Topic control work*
	Exam	

6. Student's self-training

The discipline "Discrete mathematics for computer science" is based on self-training for classroom classes on theoretical and practical topics.

No.	*The topic assigned for self-training*	*Number of hours*	*Literature*
1	*Topic 1. Sets*	*0,1*	*1*

	Preparation for lecture		
2	Preparation for the practice class	0,5	1
3	Execution of the test	0,1	1
4	Finite and infinite sets, ordered sets. ([1] p.9, [2] p.35)	2	1
5	Preparation for the topic control work	1	1
6	Topic 2. Relations Preparation for lecture	0,2	1
7	Preparation for the practice class	1	1
8	Execution of the test	0,2	1
9	The relation of tolerance. ([1] p.47, [2] p.198) Functional relationship, areas of definition and values, mapping, surjection, injection, bijection. ([1] p.54, [2] p.210)	2	1
10	Preparation for the topic control work	1	1
11	Topic 3. Algebraic structures Preparation for lecture	0,1	1
12	Homomorphism, isomorphism. ([1] p.80, [4] p.189, [7] p.76) The simplest algebraic structures. Semigroup, monoid, group, abelian group, rings and fields. ([1] p.85, [4] p.201, [7] p.77) Grids. Upper and lower faces in a partially ordered set, lattice, full lattice, one and zero lattice. ([1] p.93, [7] p.96)	2	1
13	Topic 4. Boolean functions and transformations Preparation for lecture	0,3	1
14	Preparation for the practice class	1,5	1
15	Execution of the test	0,3	1
16	Minimization of functions by the Nelson method. Minimization of functions by the Poretsky-Blake method. ([1] p.165, [2] p.257) Order relations for interpretations, signs of monotonicity of a function. ([1] p.147)	2	1
17	Preparation for the topic control work	20	1
18	Topic 5. Mathematical logic Preparation for lecture	0,1	1
19	Preparation for the practice class	0,5	1
20	Execution of the test	0,1	1
21	Calculation of statements. Language, axioms and rules of inference, completeness and non-contradiction, rules of separation and substitution, deduction theorem and its consequence, proof by the method of the opposite. ([1] p.201, [2] p.15, [4] p.151) Multi-valued logic. The emergence of multi-valued logics, the truth value of a statement, the alphabet of multi-valued logic,	2	1

	unary and binary functions, a complete system of functions of multi-valued logic. ([1] p.230)		
22	*Preparation for the topic control work*	*1*	*1*
23	*Topic 6. Graph theory* *Preparation for lecture*	*0,4*	*1*
24	*Preparation for the practice class*	*2*	*1*
25	*Execution of the test*	*0,5*	*1*
26	*Euler and semi-Eulerian graphs. Theorems on the necessary and sufficient conditions for the existence of an Euler cycle in a graph. ([1] p.246, [2] p.108, [4] p.250)* *Hamiltonian and semi-Hamiltonian graphs. Theorems on the necessary and sufficient conditions for the existence of a Hamiltonian cycle in a graph. ([1] p.304, [2] p.111, [4] p.252)* *Planar graphs. The Pontryagin-Kuratovsky theorem. Graph coloring. Problems that can be solved by coloring graphs. ([1] p.260, [2] p.126, [4] p.249)* *Study of sections and cycles in a graph. Application. ([1] p.286)* *Currents in networks. Algorithms for calculating the maximum current in a network with one source and one drain and with many sources and drains. ([1] p. 322)*	*2*	*1*
27	*Preparation for the topic control work*	*1*	*1*
28	*Topic 7. Automatic machines* *Preparation for lecture*	*0,5*	*1*
29	*Preparation for the practice class*	*0,5*	*1*
30	*Execution of the test*	*0,1*	*1*
31	*Miley and Moore automata. ([1] p.399, [2] p.314)*	*2*	*1*
32	*Preparation for the topic control work*	*1*	*1*
33	*Preparation for the exam*	*30*	*1*

Policy and control

7. Policy of academic educational component

- *Rules of behavior in classes: activity, respect for those present.*
- *Adherence to the policy of academic integrity.*
- *Rules for protecting the works of the computer workshop: the works must be done according to the option of the student, which is determined by his number in the group list.*
- *Rules for assigning incentive points: incentive points can be awarded for a creative approach in the performance of computer workshop works (maximum number of points for all works – 2 points).*

8. Rating system for evaluating learning outcomes

During the semester, students complete 6 topic control work. The maximum number of points for each: 10 points (5 tasks × 2 points).

Points are awarded for quality of work: 0-2 points;

2 points - the work is done with quality, in full;
1 point – the work contains errors;
0 points – the work contains significant errors or is borrowed.

The maximum number of points for performing and defending tasks:
6 control works × 5 tasks × 2 points = 60 points.

During the semester, quiz on the topics of past lectures take place at the lectures. Maximum points for quiz: 20 points.

The assignment for the midterm test consists of 4 questions (problems). The answer to each question is evaluated by 5 points.

Evaluation criteria for test questions:
5 points – the answer is correct, the calculations are completed in full;
4 points – the answer is correct, but not very well supported by calculations;
3 points - in general, the answer is correct, but has flaws;
2 points – there are minor errors in the answer;
1 point – there are significant errors in the answer;
0 points - there is no answer or the answer is incorrect.

The maximum number of points for the midterm test:
5 points × 4 questions = 15 points.

The rating scale for the course is equal to:

$R = 0.5 * R_S + R_E$ = 50 points + 50 points = 100 points.

R_S = 60 points + 20 points + 20 points = 100 points.

Calendar control: is carried out twice a semester as a monitoring of the current state of fulfillment of the syllabus requirements.

At the first certification (8th week), the student receives "credited" if his current rating is at least 20 points (50% of the maximum number of points a student can receive before the first certification).

At the second certification (14th week), the student receives "passed" if his current rating is at least 40 points (50% of the maximum number of points a student can receive before the second certification).

Semester control: exam.

A necessary condition for admission to the exam is the completion and defense of all the tasks.

The exam sheet contains 4 questions: 3 theoretical and 1 practical. The answer to each theory question is worth 10 points, and the answer to a practical question is worth 20 points.

Evaluation criteria for each theoretical question:
8-10 points – the answer is correct, complete, well-argued;
5-7 points – - in general, the answer is correct, but has flaws;
1-4 points – there are significant errors in the answer;
0 points - there is no answer or the answer is incorrect.

Evaluation criteria for a practical question:
18-20 points - the answer is correct, the calculations are completed in full;
14-17 points - the answer is correct, but not very well supported by calculations;
9-13 points - in general, the answer is correct, but has flaws;
5-8 points – there are minor errors in the answer;
1-4 points – there are significant errors in the answer;
0 points - there is no answer or the answer is incorrect.

The maximum number of points for the exam:
10 points × 3 theory questions + 20 points × 1 practical question = 50 points.

Table of correspondence of rating points to grades on the university scale:

Scores	*Rating*
100-95	Excellent
94-85	Very Good
84-75	Good
74-65	Satisfactory
64-60	Fair
Less than 60	Unsatisfactory
Admission conditions not met	Not allowed

The syllabus prepared by Ph.D., assoc. prof. Tetiana Likhouzova.

Approved by the PZKS department (protocol No. 13 dated 22.06.2022).

Approved by the Methodical Commission of the Faculty of Applied Mathematics (protocol No. 9 dated 24.06.2022).