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Graduate study

Discrete mathematics and its applications

General Information	
Title of study programme	Discrete mathematics and its applications
Study programme coordinator	University of Rijeka
Study programme implementor	Department of mathematics – University of Rijeka
Type of study programme	University
Level of study programme	Graduate
Academic/professional degree awarded upon completion of study	Master of Science in Mathematics - course: discrete mathematics and its applications

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STUDY PROGRAM LEARNING OUTCOMES AND COMPETENCES	
Through the study programme, students will acquire theoretical and practical knowledge which helps them find a job in economy, and moreover, acquisition of learning new skills. Furthermore, students will be able to:	
(I1.)	reasoning and problem solving in real and complex analysis
(I2.)	reasoning and problem solving in linear algebra, algebra and group theory
(I3.)	reasoning and problem solving in models of geometry with the emphasis on Euclidean geometry, using a constructive and an analytical approach
(I4.)	reasoning and problem solving in discrete and combinatorial mathematics, probability and statistics
(I5.)	reasoning and problem solving in number theory, set theory and mathematical logic
(I6.)	reasoning and problem solving in applied mathematics
(I7.)	differentiate and analyse cryptographic systems
(I8.)	differentiate and analyse different types of codes
(I9.)	differentiate methods for detecting errors in data transmission for a particular coding method and analyse conditions under which the error correctiong is possible
(I10.)	apply, with reasoning, the use of the simplex algorithm and other linear programming methods
(I11.)	reasoning about the notion of matrix games
(I12.)	reasoning and solving integer programming problems
(I13.)	conduct a procedure for testing statistical hypotheses and apply methods of statistical data analysis with or without using appropriate computer programs
(I14.)	design and analyse experiments and solve a problem while using appropriate computer programs
(I15.)	solve problems using graph theory, design theory and coding theory, and, when needed, writing advanced algorithms and implementing them in appropriate computer programs
(I16.)	classify basic and advanced approaches, methods and algorithms of artificial intelligence and machine learning, and successfully apply them in solving typical problems in the field
(I17.)	connect and apply mathematical models with approaches and methods in artificial intelligence, machine learning and data mining to solve problems using modern concepts and approaches
(I18.)	mathematically prove validity of procedures and formulae used within the courses of the study programme
(I19.)	use acquired knowledge of theorems, procedures and formulae in problem solving

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LIST OF MODULES/COURSES							
Year of study: 1							
Semester: winter							
MODULE	COURSE	COURSE INSTRUCTOR	L	E	S	ECTS	STATUS[1]
	Number theory	Assoc. Prof. Ana Jurasić, PhD	30	30	0	6	C
	Probability theory	Assoc. Prof. Danijel Krizmanić, PhD	30	30	0	6	C
	Algebra I	Assoc. prof. Marijana Butorac, PhD	30	30	0	6	C
	Graph theory	Prof. Dean Crnković, PhD	30	15	15	6	C
	Linear programming	Assoc. prof. Ana Jurasić, PhD	30	30	0	6	C
Semester: summer							
MODULE	COURSE	COURSE INSTRUCTOR	L	E	S	ECTS	STATUS
	Statistics	Asst. Prof. Ivana Slamić, PhD	30	30	0	6	C
	Algebra II	Asst. Prof. Vera Tonić, PhD	30	30	0	6	C
	Coding theory and cryptography	Asst. Prof. Nina Mostarac, PhD	30	15	15	6	C
	Mathematical foundations of artificial intelligence	Assoc. Prof. Andrea Švob, PhD	30	30	0	6	C
	Optimization techniques for data mining	Asst. Prof. Daniel R. Hawtin, PhD	30	15	15	6	C

LIST OF MODULES/COURSES							
Year of study: 2							
Semester: winter							
MODULE	COURSE	COURSE INSTRUCTOR	L	E	S	ECTS	STATUS[2]
	Permutation groups	Assoc. prof. Vedrana Mikulić Crnković, PhD	30	15	15	6	C
	Introduction to design theory	Prof. Sanja Rukavina, PhD	30	15	15	6	C
	Design and analysis of experiments	Asst. Prof. Doris Dumičić Danilović, PhD	30	15	15	6	C
	Machine learning	Asst. Prof. Sanda Bujačić Babić, PhD	30	30	0	6	C
	Internal elective course (6 ECTS on elective courses)						
	Finite geometries	Assoc. Prof. Vedrana Mikulić Crnković, PhD	30	0	15	6	E
	Methodology of teaching mathematics I	Prof. Sanja Rukavina, PhD	30	0	30	6	E
	Nonlinear optimization	Assoc. prof. Bojan Crnković, PhD	30	30	0	6	E
	Vector spaces I	Asst. Prof. Vera Tonić, PhD	30	30	0	6	E

[1] IMPORTANT: Insert C for compulsory courses or E for elective courses.
[2] IMPORTANT: Insert C for compulsory courses or E for elective courses.

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	Application of artificial intelligence in communication	Assoc. prof. Tajana Ban Kirign, PhD/ Asst. Prof. Benedikt Perak, PhD	30	0	15	6	E
	Programming for artificial intelligence	Prof. Ana Meštrović, PhD	30	30	0	6	E
Semester: summer							
MODULE	COURSE	COURSE INSTRUCTOR	L	E	S	ECTS	STATUS
	Seminar / M. Sc. thesis	Prof. Predrag Dominis Prester, PhD	0	0	30	4	C
	Graduation					4	C
	Internal elective course (22 ECTS on elective courses)						
	Vector spaces II	Assoc. prof. Ana Jurasić, PhD	30	30	0	60	E
	History of mathematics	Prof. Predrag Dominis Prester, PhD	15	0	30	3	E
	Popularization of mathematics	Assoc. Prof. Vedrana Mikulić Crnković, PhD	15	15	0	3	E
	Methodology of teaching mathematics II	Prof. Sanja Rukavina, PhD	30	0	30	6	E
	Seminar III – Foundations of mathematics	Prof. Majda Trobok, PhD	0	0	30	4	E
	Statistical practicum	Asst. Prof. Ivana Slamić, PhD	15	30	15	6	E
	Optimization methods in finance	Asst. Prof. Doris Dumičić Danilović	30	15	15	5	E
	Combinatorial and heuristic optimization	Asst. Prof. Doris Dumičić Danilović	30	30	0	6	E
	Stochastic processes	Asst. Prof. Ivana Slamić, PhD	30	30	0	6	E
	Partial differential equations	Assoc. prof. Bojan Crnković, PhD	30	30	0	6	E
	Harmonic analysis	Assoc. Prof. Davor Dragičević, PhD	30	0	15	6	E
	Introduction to combinatorial topology	Prof. Sanja Rukavina, PhD	15	15	15	5	E
	Seminar of applied discrete mathematics	Prof. Dean Crnković PhD / Asst. Prof. Sanda Bujačić Babić, PhD	0	30	15	5	E
	Measure and integral	Assoc. Prof. Davor Dragičević, PhD	30	30	0	6	E
	Neural networks	Asst. Prof. Sanda Bujačić Babić, PhD	30	30	0	6	E

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GENERAL INFORMATION		
Course coordinator	z	
Course title	Number theory	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

Number theory is a branch of mathematics which has always been considered as a motivation and foundation of all mathematics because of its simply formulated, but very difficult problems (some of which have been attempted to get solved for centuries). In solving these problems, the newest results in the fields of algebra, analysis and geometry are being applied. The main course objective is to get students familiar with the way of thinking and proving statements in the number theory, and especially with the algebraic and analytical methods in the number theory. For that purpose, it is necessary within the course to:

- analyse basic properties of integers: divisibility, prime numbers, prime factorization, Euclidean algorithm, congruencies,
- describe the solutions of quadratic congruency by using the Legendre symbol and compare those congruencies by using the quadratic law of reciprocity,
- analyse quadratic forms and display of integers by using quadratic forms, and specifically compare display of integers as sums of a fixed number of perfect squares,
- define arithmetic functions and compare basic examples,
- differentiate basic types of Diophantine equations and describe the methods of solving them,
- define elliptic curves, analyse their properties and applications in the number theory,
- apply the number theory in the public-key cryptography,
- describe algebraic methods in the number theory and their application,
- describe analytical methods in the number theory and their application.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. analyse basic properties of integers and apply those properties to simple problems in the number theory related to divisibility and divisibility algorithms (A6, B7, D6, E6, F6),
O2. calculate using modular arithmetics, solve congruency equations and systems of congruencies (A6, B7, D6, E6, F6),
O3. apply and understand the quadratic law of reciprocity and formulas for calculating the Legendre symbol, to solve quadratic congruencies (A6, B7, D6, E6, F6),
O4. describe the display of integers by using quadratic forms in simple cases, compare and classify different quadratic forms (A6, B7, D6, E6, F6),
O5. show and analyse basic multiplicative functions and their properties, check and show connections between them (A6, B6, D6, E6, F6),
O6. define basic types of Diophantine equations and describe the methods of solving them (A6, B7, D6, E6, F6),
O7. define elliptic curves, analyse their basic properties and describe important open problems (A6, B6,

D6, E6, F6),
O8. apply and understand the methods in the number theory in analysis of the public-key cryptosystem (A6, B7, D6, E6, F6),
O9. describe and analyse algebraic and analytical methods in the number theory and apply them to important problems.

1.4. Course content

Divisibility. Greatest common factor. Euclidean algorithm. Prime numbers. Congruencies. Euler theorem. Chinese remainder theorem. Primitive roots and indices. Quadratic remainders. Legendre symbol. Quadratic law of reciprocity. Divisibility properties of Fibonacci numbers. Quadratic forms. Reduction of binary quadratic forms. Distribution of prime numbers. Diophantine equations. Linear Diophantine equations. Pythagorean triples. Pell equation. Elliptic curves. Application of the number theory in the public-key cryptography.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).
Remark: 50% of exercises are held on computers, and 50% are auditory exercises.

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus).

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Dujella, A., Number Theory, Školska knjiga, Zagreb, 2021.	2	10
Dujella A., Teorija brojeva, Školska knjiga, Zagreb, 2019.	6	10
Baker: A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, 1994.	1	10
Dujella A., Maretić M.: Kriptografija, Element, Zagreb, 2007.	3	10

1.10. Additional reading

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1. Niven, H. S. Zuckerman, H. L. Montgomery: An Introduction to the Theory Numbers, Wiley, New York, 1991.
2. K. H. Rosen: Elementary Number Theory and Its Applications, Addison-Wesley, Reading, 1993.
3. K. Chandrasekharan: Introduction to Analytic Number Theory, Springer-Verlag, Berlin, 1968.
4. H. E. Rose: A Course in Number Theory, Oxford University Press, 1995.
5. W. M. Schmidt: Diophantine Approximation, Springer-Verlag, Berlin, 1996.
6. B. Pavković, D. Veljan: Elementarna matematika 2, Školska knjiga, Zagreb, 1995.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator	z	
Course title	Probability theory	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main objective of this course is to acquaint the students with the basic notions, methods and results of the probability theory. In that aim it is necessary to:

- define measures and describe basic examples of measure spaces,
- define Lebesgue measure and analyse its properties,
- define an integral of a function over a measure space and analyse its properties,
- define random variables and analyse their basic properties,
- define distribution functions and describe classification of random variables,
- define expected value and variance, and prove limit theorems for expected value,
- describe basic types of convergence of random variables and their relations,
- prove weak and strong laws of large numbers,
- describe convergence of series of random variables,
- define characteristic functions of random variables and analyse their basic properties.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course students should be able to:

O1. argumentedly apply properties of measures and integrals (A7, B7, C7),
O2. analyse examples of measures with particular emphasis on the Lebesgue measure (A7, B7, C7),
O3. argumentedly use random variables and their properties in problem solving (A7, B7, E4, F5),
O4. explain classification of random variables (A7, B7, E4, F5),
O5. argumentedly apply limit theorems for expected value (A7, B7, E4, F5),
O6. list basic types of convergence of random variables and describe their relations (A7, B7, E4, F5),
O7. describe weak and strong laws of large numbers and convergence of series of random variables (A7, B7, E4, F5),
O8. argumentedly apply properties of characteristic functions in problem solving (A7, B7, E4, F5),
O9. argumentedly apply central limit theorems (A7, B7, E4, F5),
O10. mathematically prove foundation of procedures and formulae which they use within the course (A7, B7, E4, F5).

1.4. Course content

Ring, algebra, sigma-algebra. Borel sets. Measure, Outer measure, Lebesgue measure. Random variables. Distribution functions. Classification of random variables. Expected value. Limit theorems for expected value. Convergence of random variables. Independence of random variables. Laws of large numbers. Convergence of

series of random variables. Characteristic functions. Central limit theorems.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
N. Sarapa, Teorija vjerojatnosti, Školska knjiga, Zagreb, 2002.	23	10
A. Gut, Probability: A Graduate Course, Springer, New York, 2013.	1	10
D. L. Cohn, Measure theory, Birkhäuser, New York, 2013.	2	10
S. Mardešić, Matematička analiza II, Školska knjiga, Zagreb, 1989.	5	10

1.10. Additional reading

1. R. Durrett, Probability: theory and examples, Duxbury Press, Belmont, 1996.
2. S. I. Resnick, A Probability Path, Birkhäuser, New York, 2014.
3. S. Axler, Measure, Integration & Real Analysis, Springer Open, 2020. Link: https://measure.axler.net/MIRA.pdf
4. N. Antonić, M. Vrdoljak, Mjera i integral, PMF-Matematički odjel, Zagreb, 2001.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

GENERAL INFORMATION

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Course coordinator	z	
Course title	Algebra I	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with the advanced theory of permutation groups. For this purpose, it is necessary within the course to:

- define categories and analyse different examples of categories,
- define free groups and analyze their properties,
- define modules and analyze their properties,
- define lattices of groups,
- define subgroup series and characterise different types of subgroup series,
- define solvable groups, analyze their properties and characterise them using different methods,
- define nilpotent groups, analyze their properties and characterise them using different methods.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. construct free groups, formulate, analyse and argumentatively apply the properties of free groups in solving problems (A7, B7, C7, D7, E5, F7, G7),
O2. differentiate and analyse different categories, and argumentatively apply cathegorical constructions in solving problems (A7, B7, C7, D7, E5, F7, G7),
O3. formulate and analyze the properties of the module and argumentatively apply the properties of modules in solving problems (A7, B7, C7, D7, E5, F7, G7);
O4. distinguish and analyze the properties of solvable groups and argumentatively apply the properties of solvable groups in solving problems (A7, B7, C7, D7, E5, F7, G7);
O5. distinguish and analyze the properties of nilpotent groups and argumentatively apply the properties of nilpotent groups in solving problems (A7, B7, C7, D7, E5, F7, G7);
O6. mathematically prove validity of all procedures and formulas that are used within the course (B7, F4).

1.4. Course content

Categories and functors. Free groups. Modules. Lattices and subgroup series. Solvable groups. Nilpotent groups.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a

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certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
T.W. Hungerford: Algebra, Reinhart and Winston, NY, 1989.	2	10
S. Lang, Algebra, Addison-Wesley Publishing Company, cop. 1967.	1	10

1.10. Additional reading

1. H. J. Rose: A Course on finite groups, Springer-Verlag London, 2009.
2. D. S. Dummit, R. M. Foote, Abstract algebra, 3rd edition, Wiley, 2003.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Graph theory	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 15 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with basic concepts in graph theory and applications of graph theory. For this purpose, it is necessary within the course to:

- define basic concepts in graph theory and describe their basic properties,
- define Eulerian and Hamiltonian graph, prove some of their properties and describe its applications,
- define concepts of graph connectivity, analyse properties of connected graphs and the application in constructing reliable communication networks,
- define matching and perfect matching in graphs and elaborate corresponding statements and applications,
- define basic concepts in Ramsey theory for graphs,
- define basic concepts in directed graph theory, elaborate basic properties and some applications,
- analyse and compare certain algorithms.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing the course, the students are expected to:

O1. differentiate the concepts and graphs properties and apply and understand appropriate properties and statements in solving exercises (A7, B7, C7, D7, E5, F7, G7),
O2. analyse problems of graph connectivity and related properties (A7, B7, C7, D7, E5, F7, G7),
O3. analyse Eulerian and Hamiltonian graphs and apply and understand the definitions and properties in solving exercises (A7, B7, C7, D7, E5, F7, G7),
O4. solve problems related to a matching of graphs (A7, B7, C7, D7, E5, F7, G7),
O5. apply statements and algorithms elaborated within the course (A7, B7, C7, D7, E5, F7, G7), mathematically prove validity of all procedures and formulas that are used within the course (B7, F4).

1.4. Course content

Concepts and basic properties of graphs. Eulerian tours and Hamiltonian cycles. Chinese postman problem and Fleury's algorithm. Travelling salesman problem. Graph connectivity. Reliable communication networks. Matching in graphs. Perfect matchings. Employment problem and Hungarian matching algorithm. Optimal employment problem and Kuhn-Munkres algorithm. Independent sets, coverings and cliques. Ramsey theory for graphs. Directed graphs. Application to ranking for tournament graphs. Application to one-way street traffic flow. Transport networks. Ford-Fulkerson algorithm. Topological sorting.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory

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	☒ distance learning ☐ field-based learning	☐ mentoring work ☒ other: consultations, practicum strategies

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
D.Veljan: Kombinatorika i diskretna matematika, Algoritam, Zagreb, 2001.	5	10
D.Veljan: Kombinatorika s teorijom grafova, Školska knjiga, Zagreb, 1989.	5	10

1.10. Additional reading

1. N.Biggs: Discrete Mathematics, Clarendon Press, Oxford, 1989.
2. R.Diestel: Graph Theory, Fourth edition, Springer-Verlag, New York, 2010.
3. R.Balakrishnan, K.Ranganathan: A Textbook of Graph Theory, Springer-Verlag, Heidelberg, 2000.
4. R.Balakrishnan: Schaum's outline of Graph Theory: Included Hundreds of Solved Problems, McGraw-Hill, New York, 1997.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Linear programming	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with:
- basic types of the linear programming problems,
- basic principles and algorithms for solving problems of finding minimum and maximum values,
- notions of dual problems of linear programming,
- basic notions of the matrix game theory,
- basics of convex programming,
- basics of integer programming.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:
O1. classify basic convex sets of points in n-dimensional Euclidean space and proper analytical methods of solving linear programming problems (A6, B6, C6, D6, E6, F6),
O2. apply, with reasoning, the properties of a linear (affine) function to a linear programming problem (A6, B6, C6, D6, E6, F6),
O3. define the goal function in simple linear programming problems (A6, B6, C6, D6, E6, F6),
O4. apply and understand various algorithms for finding extreme values of a linear function on a convex set (A6, B6, C6, D6, E6, F6),
O5. solve the dual problem of linear programming (A6, B6, C6, D6, E6, F6),
O6. apply and understand the Simplex algorithm (A6, B6, C6, D6, E6, F6),
O7. analyse the concept of matrix games (A6, B6, C6, D6, E6, F6),
O8. solve problems of integer programming (A6, B6, C6, D6, E6, F6),
O9. analyse the basics of convex programming (A6, B6, C6, D6, E6, F6).

1.4. Course content

Convex sets in R^n. Polyhedral sets. Gauss-Jordan method for solving system of equations. Basic linear programming problems. Fourier-Motzkin method and some graphical methods for solving linear programming problems. Simplex method. Degeneracy case. Dual simplex method. Parametric linear programming. Duality. Integer linear programming. Selected applications of linear programming (transportation problem, assignment porblem). Basics of matrix game theory. Basics of convex programming.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

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1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).
Remark: The exercises on this course will be conducted in classroom form (10 hours) and on computers (20 hours).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
F, S. Hillier, G. J. Lieberman, Introduction to Operations Research, Ninth Edition, McGraw Hill, New York, 2010.	http://www.maths.lse.ac.uk/Personal/stengel/HillierLieberman9thEdition.pdf	15
N. Limić, H.Pašagić, Č.Rnjak : Linearno i nelinearno programiranje, Informator, Zagreb, 1978.	5	15
R. J. Vanderbei, Linear programming: foundations and extensions, 2nd ed., Kluwer, 2001.	www.princeton.edu/~rvdb/LPbook	15

1.10. Additional reading

1. R.V. Benson : Euclidean Geometry and Convexity, Mc Graw - Hill, NY, 1966.
2. L.Lyusternik : Convex Figures and Polyhedrons, Dover publications, NY, 1963.
3. M.Radić : Linearno programiranje, Školska knjiga, Zgb, 1974.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Statistics	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main objective of the course is to familiarise students with the basic ideas and concepts of mathematical statistics. For that purpose, it is necessary within the course to:

- demonstrate the basic tools for presentation of statistical data,
- describe the classification of statistical variables,
- define the parameters of a sequence of statistical data,
- analyse continuous random variables and vectors that are important in statistical analysis,
- define estimators and describe their properties,
- define confidence intervals,
- define and analyse the concept of statistical test,
- describe methods of hypothesis testing,
- enable students to independently use computer software for statistical data analysis.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. present statistical data in tabular and graphical form (A7, B7, E4, F5),
O2. classify statistical variables (A7, B7, E4, F5),
O3. analyse continuous random variables and vectors that are used in statistics (A7, B7, E4, F5),
O4. use and understand the concept of estimators and their properties within the specific statistical models (A7, B7, E4, F5),
O5. using a computer, construct confidence intervals and conduct a procedure of testing statistical hypotheses (A7, B7, E4, F5),
O6. using a computer, apply methods of statistical data analysis (A7, B7, E4, F5),
O7. mathematically prove validity of all procedures and formulas that are used within the course (A7, B7, E4, F5).

1.4. Course content

Descriptive statistics. Continuous random variables and vectors. Conditional distributions and mathematical expectation. Statistical structure. Estimations of parameters. Confidence intervals. Statistical hypothesis testing. ANOVA. Linear regression models.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work

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	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	X
Project		Continuous assessment	X	Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Ž.Pauše, Uvod u matematičku statistiku, Školska knjiga, Zagreb, 1993.	3	10
F.Daly, D.J.Hand, M.C.Jones, A.D.Lunn, K.J.McConway, Elements of Statistics, Addison Wesley, 1995.	1	10

1.10. Additional reading

1. N.Sarapa, Vjerojatnost i statsistika, II dio, Školska knjiga, Zagreb, 1996.
2. R.C.Mittelhammer, Mathematical statistics for economics and business, Springer Verlag, New York, 1996.
3. J.E.Freund, Mathematical Statistics, Prentice Hall, New York, 1992.
4. D.Williams, Weighing the Odds, Cambridge University Press, 2001.
5. R.B.Ash, Lectures on Statistics, University of Illinois, 2007.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Algebra II	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with:
- basic notions of ring theory, especially theory of polynomial rings,
- basic notions of field theory and field extension theory,
- basic notions of Galois theory.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:
O1. define, give examples and recognise basic algebraic structures with two operations (A7, B7),
O2. have knowledge of the concept of ring, ideal and ring homomorphism (A7, B7),
O3. have knowledge of basic theorems of polynomial theory and be able to prove them (F3, B7),
O4. have knowledge of various types of field extensions and properly apply them (A7, B7, C7),
O5. successfully solve problems of determining Galois group (A7, B7),
O6. have knowledge of basics of Galois theory (A7, B7).

1.4. Course content

Rings and ideals. Integral domains. Euclidean domains, principal ideal domains, unique factorisation domains. Polynomial rings. Field extensions (simple, algebraic, finite dimensional, normal, separable, radical). Field automorphisms and Galois groups, Galois field extensions and Fundamental Theorem of Galois theory. Splitting fields for polynomials and algebraic closure. Solvability of Galois group as a condition for solvability of an algebraic equation in radicals. Finite fields.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☐ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

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Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
T.W. Hungerford : Algebra, Reinhart and Winston, NY, 1989.	2	10
H. Kraljević : Algebra, Skripta za predavanja održana 2006/07 na Sveučilištu u Osijeku	https://web.math.pmf.unizg.hr/~hrk/nastava/2006-07/algebra_Osijek_2006_7.pdf	10

1.10. Additional reading

1. I.Stewart : Galois Theory, Chapmann and Hall, London, 1973.
2. B. Širola : Prsteni, polja i algebre, Skripta za Algebarske Strukture na PMF-u u Zagrebu

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Coding theory and cryptography	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 15 + 15

COURSE DESCRIPTION

1.1. Course objectives

Main course objective is to get students acquainted with basic cryptography systems and basic methods in coding theory. For that purpose, it is necessary within the course to:

- describe, compare and apply different cryptography systems,
- analyse the basic principles of cryptanalysis,
- analyse the basic principles of coding theory,
- define, differentiate and apply coding methods,
- analyse error detection methods in coding,
- describe methods of correcting errors in coding.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course students should be able to:

O1. differentiate and analyse cryptography systems, apply and understand adequate methods while solving problems (A7, B7, C7, D7, E5, F7, G7),

O2. analyse and differentiate different types of codes, apply and understand adequate methods while solving problems (A7, B7, C7, D7, E5, F7, G7),

O3. differentiate methods of detecting errors in data transfer with particular coding method, and analyse the conditions under which it is possible to correct the errors (A7, B7, C5, D5, E5, F5, G5),

O4. mathematically prove validity of all procedures and formulas that are used within the course (B7, F4).

1.4. Course content

Introduction to cryptography. Classical cryptography. Encryption standards. Public-key cryptography. Introduction to coding theory. Linear codes. Cyclic codes. BCH codes. Reed-Solomon codes. Perfect codes.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

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1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')							
Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
A. Dujella: Kriptografija, skripta	http://web.math.hr/~duje/kript/kriptografija.html	15
J.I. Hall, Notes on Coding Theory, 2010	http://www.math.msu.edu/~jhall/classes/codenotes/coding-notes.html)	15
Igor S. Pandžić, Alen Bažant, Željko Ilić, Zdenko Vrdoljak, Mladen Kos, Vjekoslav Sinković: Uvod u teoriju informacija i kodiranja, Element, 2009	5	15

1.10. Additional reading

1. E.F. Assmus, J.D. Key, Designs and their codes, Cambridge University Press, London, 1992.
2. A. Dujella, M. Maretić, Kriptografija, Element, Zagreb, 2007.
3. N. Koblitz, A Course in Number Theory and Cryptography, Springer Verlag, New York, 1994.
4. J.H. van Lint, Introduction to Coding Theory, Springer-Verlag, Berlin, 1982.
5. F.J. MacWilliams, N.J.A. Sloane, The theory of error-correcting codes, North-Holland, 1977.
6. B.Schneiner, Applied Cryptography, Wiley, NY 1995.
7. J. Seberry, J. Pieprzyk, Cryptography: an introduction to computer security, Prentice-Hall, 1989.
8. D.R.Stinson, Cryptography. Theory and Practice, CRC Press, Boca Raton, 1996.

D. Welsh, Codes and cryptography, Oxford: Clarendon Press, 1988.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Mathematical foundations of artificial intelligence	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30+30+0

COURSE DESCRIPTION

1.1. Course objectives

The objective of this course is to get students acquainted with some some basic issues and algorithms in artificial intelligence. For this aim it is needed to:

- approach to artificial intelligence from an algorithmic, computer science perspective,
- provide some basic tools and algorithms required to produce artificial intelligence systems in the form of representing and reasoning with knowledge, planning and learning,
- introduce logic programming language associated with artificial intelligence.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing the course, students will be able to:

O1. analyse different perspectives on what are the problems of artificial intelligence, (A5, B5,C5,D3,E4,F7,G7),
O2. explain the basic knowledge representation, problem solving, and learning methods of artificial Intelligence, (A5, B5, C5, D3, E4,F7,G7),
O3. assess the applicability, strengths, and weaknesses of the basic knowledge representation, problem solving, and learning methods in solving particular problems, (A5, B5,C5,D5,E4,F7,G7),
O4. develop intelligent systems through examples of concrete computational problems, (A7, B6, C6,D5,F7,G7),
O5. design basic problem solving methods based on artificial intelligence - based search, reasoning, planning, and learning algorithms, (A7,B7,C5,D5,E4,F7,G7),
O6. describe logic programming language associated with artificial intelligence. (A5,B5,C4,E3,F4).

1.4. Course content

Perspectives and issues in artificial intelligence. History of development. Basic methods and theories. Problem solving. Knowledge representation and reasoning. Learning. Logic programming language associated with artificial intelligence.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

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Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
S. J. Russell, P. Norvig, Artificial Intelligence, A Modern Approach, Prentice Hall; 3rd edition, New Jersey,2010. http://aima.cs.berkeley.edu/	9	10

1.10. Additional reading

G. F. Luger, Artificial Intelligence: Structures and Strategies for Complex Problem Solving. Addison-Wesley, 2005.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Optimization techniques for data mining	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	1.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30+20+10

COURSE DESCRIPTION

1.1. Course objectives

The goal of the course is to acquire a basic knowledge of databases, with particular emphasis on relational databases, and to familiarize students with terms, algorithms, and mathematical techniques used in data mining, i.e., discovering patterns in large data sets. For this purpose, the course will include:

- introducing basic concepts about databases and performing simple and complex database queries,
- introducing basic concepts and algorithms related to data mining,
- illustratrating the application of the developed algorithms in data mining,
- connecting different branches of mathematics (especially probability and statistics) as a theoretical basis for most algorithms in data mining,
- introducing a programming language for data mining,
- introduce programming language associated with data mining.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing the course, students will be able to:

O1. explain basic concepts from database theory and concepts of the relational data model (A4, B5, C5, E4, F4, G4),
O2. analyze and process a large amount of data (A5, B5, C5, E5, F5, G4),
O3. define and understand the basic concepts of data mining (A4, B5, C5, E4, F4),
O4. describe the basic techniques of data mining (A5, B5, C5, E4, F4),
O5. analyze and compare different algorithms for data mining (A5, B5, C5, E4, F4),
O6. solve problems typical for data mining (A5, B5, C6, D5, E4, F4, G7),
O7. design simple algorithms for data mining (A7, B5, C7, D4, E4, F7, G7),
O8. evaluate the effectiveness of the algorithms presented (A7, B6, C7, D5, E5, F7, G7).

1.4. Course content

Introduction to databases. Relational data model. Relational algebra. Performing database queries. Operations in the relational model. Introduction to data mining. Data warehouses. Data analysis and processing. Discovery and presentation of knowledge in mining. Algorithms in data mining: associative rule, classification, prediction. Evaluation of knowledge. Implementation of mining in real databases. Clustering. Advanced methods in data mining.

1.5. Types of teaching (add an 'X')		
	☐ lectures	☐ independent tasks
	☐ seminars and workshops	☐ multimedia and network
	☐ practicals	☐ laboratory

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	☐ distance learning ☐ field-based learning	☐ mentoring work ☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
J. Leskovec, A. Rajaraman, J. D. Ullman, Mining of Massive Datasets, Cambridge University Press, 2014.	3	10
Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data Mining, 2nd ed., Pearson, 2019.	2	10

1.10. Additional reading

1. B. Schölkopf, A. J. Smola, Learning with Kernels. Support Vector Machines, Regularization, Optimization, and Beyond, MIT Press, Massachusetts, 2002.

T. Hastie, R.Tibshirani, J. Friedman, Data Mining, Inference, and Prediction, Springer-Verlag New York, 2009.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Permutation groups	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 15 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with the advanced theory of the permutation groups. For this purpose it is necessary within the course to:

- define the action of a group on a set, differentiate various actions and analyse their properties,
- define a permutation group, differentiate various examples of a permutation group and analyse its properties,
- descrabe the constructions of primitive groups and O'Nan-Scott theorem and analyse its consequences,
- provide a short introduction into the theory of finite simple groups.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course the students are expected to:

O1. differentiate and analyse various actions of a group on a set, apply and understand adequate methods while solving problems (A7, B7, C7, D7, E5, F7, G7),
O2. differentiate and analyse various examples of permutation groups, apply and understand adequate procedures while solving problems (A7, B7, C7, D7, E5, F7, G7),
O3. construct different finite structures from permutation groups and analyse their properties (A7, B7, C7, D7, E5, F7, G7),
O4. apply and understand O'Nan-Scott theorem and its consequences (A7, B7, C7, D7, E5, F7, G7),
O5. describe classification of finite simple groups (A5, B5, C5, D5, E5, F4, G4),
O6. mathematically prove validity of all procedures and formulas that are used within the course (B7, F4).

1.4. Course content

Transitive and k-transitive groups. Regular groups. Primitive groups. O'Nan-Scott theorem and consequences. Simple groups. Construction of incidence structures from groups.

1.5. Types of teaching (add an 'X')	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the

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course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
P. J. Cameron, Permutation groups, Cambridge University Press, 1999.	1	10
J. D. Dixon, B. Mortimer, Permutation groups, Springer, New York, 1996.	1	10

1.10. Additional reading

/

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Introduction to design theory	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 15 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with:
- the basic definitions, concepts, procedures and theorems of the design theory,
- the relation between different combinatorial structures, link designs with codes, graphs, differential sets, latin squares,
- basic applications of a combinatorial design in the coding theory, to threshold schemes, visual cryptography and group testing.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:
O1. define the basic concepts of the design theory, apply and understand some basic procedures in the design theory (A7, B7),
O2. have knowledge of the basic theorems of the design theory and be able to prove them (B7, F4),
O3. construct examples of block designes and related combinatorial structures (C7, D7, E5, F7, G7),
O4. apply the design theory in the elementary problems of the coding theory, threshold schemes, visual cryptography and group testing (A7, B7, C7).

1.4. Course content

Basic definitions and properties of combinatorial designes; incidence matrices, isomorfisms and automorfisms, Fisher's inequality. Symmetric designs; differential sets, construction of differential sets, residual and derived designs, Hadamard matrices and designs, Bruck-Ryser-Chowla theorem. Resolvable designs; affine plane, projective plane, Bose's inequality, affine resolvable design. Steiner triple system; quasigroups, the Bose construction, the Skolem construction, cyclic Steiner triple systems. Orthogonal latin squares; mutually orthogonal latin squares, orthogonal arrays and transversal designs.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☒ other: consultations

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the

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course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project	X	Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
D.R. Stinson: Combinatorial Designs with Selected Applications, Lecture Notes	www.cacr.math.uwaterloo.ca/~dstinson/papers/designnotes.ps)	10
E. F. Assmus, J. D. Key: Designs and their Codes, Cambridge University Press, 1992	2	10

1.10. Additional reading

1. Anderson, I. Honkala: A Short Course in Combinatorial Designs, Internet Edition, 1997. www.utu.fi/~honkala/designs.ps

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Design and analysis of experiments	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 15 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with the procedures for designing and analysing experiments and enable them to carry out these procedures in specific situations. For this purpose, it is necessary within the course to:

- describe basic principles and methods for designing experiments,
- define and analyse some standard experimental designs,
- describe and analyse a model for designs with one source of variation,
- describe and analyse contrasts,
- define and compare methods of multiple comparisons,
- analyse methods for checking model assumptions,
- analyse experiments with two or more crossed treatment factors,
- define and analyse complete block designs,
- update the knowledge about basic notions from design theory,
- describe and analyse basic notions in statistical design theory.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. describe and apply with understanding the basic principles and methods for designing and analysing experiments to particular examples in this field (A7, B7, E5, F5),
O2. analyse the model for designs with one source of variation (A7, B7, E4, F5),
O3. analyse and apply with understanding the methods of multiple comparisons (A7, B7, E4, F5),
O4. analyse models for two treatment factors (A7, B7, E4, F5),
O5. use the appropriate software package for solving problems in this field (A7, B7, E4, F5),
O6. analyse basic notions in statistical design theory (A7, B7, E4, F5),
O7. apply and use basic notions in statistical design theory to particular examples (A7, B7, E4, F5),
O8. mathematically prove validity of all procedures and formulas that are used within the course (A7, B7, E4, F5).

1.4. Course content

Basic principles and techniques for designing experiments. Planning experiments. Some standard experimental designs. Designs with one source of variation. Contrasts. Methods of multiple comparisons. Checking model assumptions. Experiments with two or more crossed treatment factors. Complete block designs. Statistical design theory.

1.5. Types of teaching	☒ lectures	☒ independent tasks

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(add an 'X')	☒ seminars and workshops ☒ practicals ☒ distance learning ☐ field-based learning	☒ multimedia and network ☐ laboratory ☐ mentoring work ☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project	X	Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Dean, D. Voss: Design and Analysis of Experiments, Springer, 1999.	1	10
D.C. Montgomery, Design and Analysis of Experiments, 5th Edn. J. Wiley., 2004.	2	10
D.C. Montgomery, Design and Analysis of Experiments, 5th Edn. J. Wiley., 2004.	http://www.ru.ac.bd/stat/wp-content/uploads/sites/25/2019/03/502_06_Montgomery-Design-and-analysis-of-experiments-2012.pdf	10

1.10. Additional reading

1. W.Feller, An Introduction to Probability Theory and Aplication, J.Wiley, New York, 1966.
2. N.Sarapa, Vjerojatnost i statistika, II dio, Školska knjiga, Zagreb, 1996.
3. C.M.Grinstead, J.L.Snell, Introduction to Probablility, American Mathematical Society, 1997. http://aleph0.clarku.edu/~djoyce/ma217/book-5-17-03.pdf
4. K.L.Chung, A Course in Probability Theory, Academic Press, 2000.
5. R.Durrett, Probability: theory and examples, Duxbury Press, Belmont, 1996.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Machine learning	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30+30+0

COURSE DESCRIPTION

1.1. Course objectives

The goal of the course is to provide students with some basic concepts and the most popular approaches to machine learning. During the course, students will learn about machine learning algorithms and various practical applications. For this purpose, it is necessary to:

- define basic concepts of machine learning,
- describe and apply basic machine learning approaches: supervised learning (regression, classification) and unsupervised learning (clustering),
- describe and apply various machine learning algorithms,
- introduce and apply a programming language in solving typical machine learning problems.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing the course, students will be able to:

O1. define the basic concepts and approaches of machine learning (A5, B5, C5, E3, F4),
O2. identify problems and features where machine learning techniques have been successfully applied (A5, B5, C5, D5, E4, F7, G6),
O3. relate and apply numerous mathematical models, primarily from the fields of linear algebra, probability and statistics, graph theory and optimization, used in algorithms and machine learning techniques (A6, B5, C5, D5, E5, F7, G6),
O4. distinguish and analyze various machine learning algorithms (A5, B5, C5, E4, F4, G4),
O5. prove and apply mathematical laws and tools underlying machine learning algorithms (A6, B5, C5, D5, E5, F7, G6),
O6. apply machine learning algorithms to practical problems (A5, B5, C5, D3, E4, F7, G6).

1.4. Course content

Introduction to machine learning: basic concepts, definitions, approaches. The concept of learning. Regression. Classification. Logistic and softmax regression. Generalized linear models. Gaussian discriminant analysis. Naive Bayes classifier. Laplace smoothing. Kernel functions. Kernel trick. Support vector machine. Neural networks. Decision tree. Random forests. The k-nearest neighbor algorithm. Bias - variance. Regularization. Selection of models and properties. Expectation maximization algorithm.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

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1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
E. Alpaydin, Introduction to Machine Learning, The MIT Press, 2009.	5	10
T. M. Mitchell, Machine Learning, McGraw-Hill Science, 1997.	4	10

1.10. Additional reading

1. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2007.

Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, 2nd Edition

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Finite geometries	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 0 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with the finite geometry theory. For this purpose, it is necessary within the course to:

- define affine and projective spaces over finite fields, a finite projective and a finite affine geometry, analyse properties of the mentioned spaces (geometries),
- analyse relationship between affine and projective spaces,
- introduce the coordinatization of a projective space,
- define and analyse a transformation of a projective space, especially dualities and polarities,
- define a dual and a polar space and analyse their properties,
- describe quadratics in projective spaces,
- analyse properties of finite projective planes,
- describe, analyse and differentiate Desargues and non-Desargues projective planes,
- describe, analyse and differentiate polarities and quadratics in finite projective planes.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. define basic concepts of finite geometry theories, apply and understand basic procedures in problem solving (A7, B7, C5, D5, E5, F5, G5),
O2. differentiate and analyse transformations of a projective space, apply and understand appropriate procedures in problem solving (A7, B7, C5, D5, E5, F5, G5),
O3. analyse and differentiate various finite projective planes, apply and understand appropriate procedures in problem solving (A7, B7, C7, D7, E5, F7, G7),
O4. analyse and differentiate polarities and quadratics in finite projective planes, apply and understand appropriate procedures in problem solving (A7, B7, C7, D7, E5, F7, G7)
O5. mathematically prove validity of all procedures and formulas that are used within the course (B7, F4).

1.4. Course content

Projective and affine spaces over finite fields. Projective space coordination. Projective space and transformation. Dualities and polarities in projective spaces. Dual and polar spaces. Squares in projective spaces. Finite projective planes. Desargues and non-desargues projective planes. Polarities and quadratics in finite projective planes.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☐ practicals	☐ laboratory

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	☒ distance learning ☐ field-based learning	☒ mentoring work ☒ other: consulations

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
P. J. Cameron, Projective and Polar Spaces	http://quoll.uwaterloo.ca/mine/Notes/fgeom.pdf	5
C. D. Godsil, Finite geometry	http://quoll.uwaterloo.ca/mine/Notes/fgeom.pdf	5

1.10. Additional reading

1. H.S.M.Coxeter: Projektivna geometrija, Školska knjiga, Zagreb, 1982.
2. V. Krčadinac, Unitali, skripta, http://web.math.hr/~krcko/radovi/unitali10.pdf
3. D.Palman: Projektivna geometrija, Školska knjiga, Zagreb, 1984.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Methodology of teaching mathematics I	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 0 + 30

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with practical and theoretical aspects of the methods for teaching mathematics in higher grades of elementary schools and in secondary schools. For this purpose, it is necessary within the course to:

- define and analyse basic and special theories of teaching mathematics in higher grades of elementary schools and in secondary schools,
- prepare students for organizing a math teaching class in accordance with teaching principles,
- introduce the national curriculum for mathematics in higher grades of elementary schools and in secondary schools,
- acquaint students with the mathematical knowledge that is necessary for effective teaching of mathematics in higher grades of elementary schools and in secondary schools.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. quote the principles of mathematics education and their basic properties, and use them with understanding (A7, B6, C6, D6, E6, F6),
O2. differentiate several forms of defining mathematical terms and highlight their advantages and deficiencies in school mathematics (A7, B6, C6, D6, E6, F6),
O3. interpret and compare different ways of proving mathematical theorems (A7, B6, C6, D6, E6, F6),
O4. analyse the national curriculum of mathematics in higher grades of elementary schools and in secondary schools (A6, B6, C5, D6, E5, F5),
O5. in accordance with the principles of teaching mathematics, clearly and precisely present mathematical content using teaching aids and facilities (A6, B6, C6, D6, E7, F7),
O6. use relevant and recent professional literature independently and critically (A6, B6, C6, D5, E7, F7),
O7. cooperate with colleagues to acquire and develop professional competences, and use the feedback in the aim of improving the teaching process (A6, B6, C5, D6, E7, F7),
O8. use the basic communication principles and techniques of effective professional communication, and express themselves accurately and fluently in spoken and written forms of communication in the language of teaching and in the official language (A6, B6, C6, D6, E6, F6).

1.4. Course content

The subject of teaching mathematics. The objectives and tasks of teaching mathematics. Principles of teaching mathematics – scientific approach (an axiom, a mathematical definition, the definition of a term, a theorem, a proof), activity, independence and awareness (a formalism in mathematics class), motivation (games in teaching mathematics, mathematical billboard), individualization, visualization, suitability (factors that affect

on the process of learning mathematics, degrees of knowing the mathematics, mathematical personality), systematicity, stability (remembering mathematical facts and procedures). In seminars, students will become familiar with the mathematical curriculum in the higher grades of elementary school and present selected topics in mathematics that are processed in the higher grades of elementary schools or in secondary school.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☐ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Current textbooks for elementary and secondary schools	20	5
Curriculum for the subject of Mathematics for elementary schools and high schools in the Republic of Croatia	https://narodne-novine.nn.hr/clanci/sluzbeni/2019_01_7_146.html	5
Matematika bez suza, ed. Ilona Posokhova, Ostvarenje, Lekenik, 2000.	6	5
Kurnik: Oblici matematičkog mišljenja, Element, Zagreb, 2013.	1	5
Kurnik: Posebne metode rješavanja matematičkih problema, Element, Zagreb, 2010.	2	5
Kurnik: Znanstveni okvir nastave matematike, Element, Zagreb, 2009.	2	5

1.10. Additional reading

1. Polya, G.: Kako ću riješiti matematički zadatak, Školska knjiga, Zagreb, 1984.
2. XXX: Matematika i škola, časopis za nastavu matematike, Element, Zagreb
3. Available methodical and popularization journals

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

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At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Nonlinear optimization	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30+30+0

COURSE DESCRIPTION

1.1. Course objectives

Mathematical optimization is at the core of every decision support methods and the cornerstone of Machine Learning and Artificial Intelligence. It has applications in Industrial applications, softer development and scientific research. In most of mentioned applications the objective and constraints are nonlinear functions of many variables which can be a hard problem to tackle without a proper tool. This course presents theoretical foundation, methods and numerical algorithms to solve optimization problems.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

On completion of this course students will:

O1. be able to list different methods of nonlinear optimization (A2, B3),
O2. be able to formulate problems in nonlinear optimization and appreciate their assumptions and limitations (A6, B6, C6),
O3. be able to choose appropriate method for solving nonlinear optimization problem using modern optimization methods and software (A7, C7, D6, E7).

1.4. Course content

Line search and trust-region methods for unconstrained optimization problems (steepest descent, Newton's method); gradient-based algorithms; linear and nonlinear least-squares. First-order and second-order optimality conditions for constrained optimization problems; overview of methods for constrained problems (active-set methods, sequential quadratic programming, interior point methods, penalty methods, filter methods).

1.5. Types of teaching (add an 'X')		
	☐ lectures	☐ independent tasks
	☐ seminars and workshops	☐ multimedia and network
	☐ practicals	☐ laboratory
	☐ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course		Activity /		Seminar		Experimental work	

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attendance		Participation		paper			
Written exam		Oral exam		Essay		Research	
Project		Continuous assessment		Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Bertsekas, Dimitri P. Nonlinear Programming. 3nd ed. Athena Scientific Press, 1999.	5	5

1.10. Additional reading

1. Hart, W.E., Laird, C.D., Watson, J.-P., Woodruff, D.L., Hackebeil, G.A., Nicholson, B.L., Siirola, J.D. Pyomo – Optimization Modeling in Python, 2017.
2. Optimization Methods in Finance, G. Cornuejols and R. Tütüncü, Cambridge University Press. ISBN-10: 0521861705 https://nlopt.readthedocs.io/en/latest/

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Vector spaces I	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with basic concepts of vector space theory. For this purpose, it is necessary within the course to:

- define vector space and describe characteristic examples of vector spaces,
- define linear operators and analyse their properties,
- analyse matrix representation of a linear operator,
- define adjoint space,
- define and analyse invariant subspaces and operator eigenvalues,
- describe reduction of operator on finite dimensional vector spaces and finding the Jordan form of the operator matrix ,
- define bilinear form and unitary space,
- define and describe properties of a normal operator.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. know basic examples of vector spaces and linear operators (A6, B6, C6, D4, E4, F3),
O2. solve problems related to the calculation of the rank (A6, B6, C6, D4, E5, F3),
O3. solve problems related to adjoint spaces (A6, B6, D4, E5, F3),
O4. construct Jordan basis (A6, B6, C6, D4, E5, F3),
O5. apply and understand the procedure of reduction of an operator on finite dimensional vector spaces in particular problems of determining the Jordan form (A6, B6, D4, E5, F3),
O6. know bacis examples of unitary spaces (A6, B7, D4, E5, F3),
O7. classify main properties of bilinear forms (A6, B6, D4, E5, F3),
O8. classify main properties and examples of normal operators (A6, B6, D4, E5, F3),
O9. mathematically prove validity of all procedures and formulas that are used within the course (A6, B6, D4, E5, F3).

1.4. Course content

Vector space, basic notions and examples. Quotient space. Linear operators, basic notions and examples. The space L(X,Y). Algebra. Characteristic and minimal polynomial. Adjoint space and adjoint operator.
Invariant subspaces and eigenvalues. Nilpotent operator. Reduction of operators on finite dimensional vector spaces. Jordan form of the operator matrix. Operator functions. Geometry of unitary spaces. The structure of bilinear forms. Normal operators.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☐ multimedia and network

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	☒ practicals ☐ distance learning ☐ field-based learning	☐ laboratory ☐ mentoring work ☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
G. Muić, M. Primc, *Vektorski prostori*, skripta, Matematički odsjek, PMF, Zagreb	https://www.pmf.unizg.hr/_download/repository/vp%5B1%5D.pdf	10

1.10. Additional reading

1. S. Kurepa, Konačno dimenzionalni vektorski prostori i primjene, Sveučilišna naklada Liber, Zagreb, 1976.
2. H. Kraljević, Vektorski prostori, skripta, Odjel za matematiku, Sveučilište u Osijeku
3. P.R. Halmos, Finite Dimensional Vector Spaces, Van Nostrand, New York, 1958.
4. K. Horvatić, Linearna algebra, Golden marketing Tehnička knjiga, Zagreb, 2004.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Application of artificial intelligence in communication	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 0 + 15

COURSE DESCRIPTION

1.1. Course objectives

Students should understand and critically judge the social and cultural implications of the digitalization of society and computer-assisted communication systems based on the application of artificial intelligence.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After taking the course and passing the exam, students will:

O1. understand and apply the mathematical and algorithmic foundations of artificial intelligence in the development of communication technologies between humans and computers, as well as assistive technologies,

O2. understand and apply natural language processing methods, such as tokenization, lemmatization, semantic analysis, sentiment analysis, and machine translation,

O3. explain and analyze different methods and techniques of deep learning and the principles of creating large language models and their application in different contexts, including communication and assistance,

O4. understand and research current and future trends in the development of artificial intelligence, deep learning and natural language processing, in order to improve communication between humans and computers and encourage innovative development in the field of technology.

1.4. Course content

Application of artificial intelligence in the development of communication technologies between humans and computers. Implications of the application of artificial intelligence and digital communication technologies. Principles of neural network learning. Deep learning architectures.
Application of artificial intelligence in natural language processing processes. Language tasks: segmentation of language structures, identification of noun entities, summarizing text, answering questions, classifying text. Application of collaborative technological frameworks and language models for conversation design and implementation of conversational assistants in social interaction.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☐ multimedia and network
	☒ practicals	☐ laboratory
	☐ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a

certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam	X	Essay		Research	X
Project		Continuous assessment	X	Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Luo, B., Lau, R. Y., Li, C., & Si, Y. W. (2021). A critical review of state-of-the-art chatbot designs and applications. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*	https://wires.onlinelibrary.wiley.com/doi/10.1002/widm.1434	5
Bowman, Samuel R. "Eight Things to Know about Large Language Models." *arXiv preprint arXiv:2304.00612* (2023).	https://arxiv.org/abs/2304.00612	5
Digitalna istraživačka infrastruktura za umjetnost i humanistiku u Republici Hrvatskoj	http://dariah.hr/	5
Rapp, A., Curti, L., & Boldi, A. (2021). The human side of human-chatbot interaction: A systematic literature review of ten years of research on text-based chatbots. *International Journal of Human-Computer Studies*, 102630.	https://www.sciencedirect.com/science/article/abs/pii/S1071581	5

1.10. Additional reading

1. E. Kasneci, K. Seßler, S. Küchemann, M. Bannert, D. Dementieva, F. Fischer, U.Gasser et al. "ChatGPT for good? On opportunities and challenges of large language models for education." *Learning and Individual Differences* 103 (2023): 102274., https://edarxiv.org/5er8f/
2. Stranica Europske komisije: https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_hr
3. *HuggingFace* platforma za dohvaćanje jezičnih modela i zadataka prirodne obrade jezika, https://huggingface.co/
4. Nikhil Buduma (2016.), *Fundamentals of Deep Learning*, O'Reilly Media
5. Fumić, P. (2021). *Duboko učenje: pregled područja* (Doctoral dissertation, University of Zagreb. Faculty of Organization and Informatics. Department of Quantitative Methods).
6. Tensorflow Deep learning demo: https://playground.tensorflow.org/

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Programming for artificial intelligence	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main objective of the course is to familiarize students with the programming for the field of artificial intelligence. The aim of the course is to learn how to apply numerical linear algebra, procedures for preparing data for processing, and declarative programming in the implementation of components of intelligent information systems.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After fulfilling all the responsibilities prescribed by the course, students are expected to be able to:

O1. Implement the chosen technique of numerical linear algebra to solve a given problem in the field of artificial intelligence.
O2. Choose an efficient numerical algorithm for a special class of matrices that is recognized in a given problem from the field of artificial intelligence with reference to the possible consequences of ill-conditioned matrices.
O3. Critically evaluate and select appropriate declarative programming techniques for solving the given problem in the field of artificial intelligence.
O4. Apply advanced programming techniques based on combining declarative programming and other programming paradigms to accessing data and preparing data for processing.
O5. Develop components for processing large amounts of data using processing methods appropriate to the given problem (e.g. parallel, distributed, network, multi-agent, etc.).
O6. Implement modules of intelligent information systems using programming languages for artificial intelligence and data analytics with the application of appropriate program modules.
O7. Develop a prototype of an intelligent information system for processing large data sets using programming languages and libraries for artificial intelligence and data analytics.
O8. Develop automated procedures for testing individual components of an intelligent information system using techniques appropriate to the given problem.

1.4. Course content

The course includes the following topics:

- Application of numerical linear algebra to solve a given problem in the field of multivariate statistics, machine learning and artificial intelligence. Implement the given method of numerical linear algebra in a suitable programming language. Numerical algorithms for a numerical algorithm for a special class of matrices (symmetric, Hermitian, normal, unitary, positive definite).
- Overview of the consequences of ill-conditioned matrices on the accuracy and speed of convergence of iterative algorithms of numerical linear algebra.
- Advanced programming techniques for accessing data and preparing data for processing. Data handling: data collection, data models, common data set problems, data transformation, data

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cleansing. Overview of approaches in processing large amounts of data: parallel, distributed, network, multi-agent, etc.
- Domain-specific languages (syntax, semantics, pragmatics) and metaprogramming techniques (eg BNF grammars, finite automata, regular languages, etc.).
- Application of appropriate program modules for artificial intelligence and data analytics. Automated component testing procedures.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☐ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam		Essay		Research	
Project	X	Continuous assessment		Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Russell, Stuart, and Peter Norvig. "Artificial intelligence: a modern approach." (2010.)	4	5

1.10. Additional reading

1. Charniak, Eugene, Christopher K. Riesbeck, Drew V. McDermott, and James R. Meehan. Artificial intelligence programming. Psychology Press, 2014.
2. Subhash Sharma (1995.), Applied multivariate techniques, John Wiley & Sons
3. Mark Hall, Ian W. Witten, Eibe Frank, Mark A. Hall, Christopher J. Pall (2017.), Data Mining, Practical Machine Learning Tools and Techniques, Morgan Kaufmann

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Seminar / M.Sc. thesis	
Study programme	Discrete mathematics and its applications	
Course status	Compulsory	
Year	2.	
ECTS credits and form of instruction	ECTS credits	4
	Number of hours (L+P+S)	0 + 0 + 30

COURSE DESCRIPTION

1.1. Course objectives

This seminar is the first step towards graduate thesis. The objective of the seminar is to enable students for:
- independent research and work with mathematical literature,
- presentation of mathematical contents.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:
O1. present mathematical concepts using teaching aids and facilities (B7, C6, D6, E6, F6),
O2. express correctly and fluently in speaking communication in the language of teaching and official language (D6),
O3. use different communication types and forms (D5),
O4. use relevant and recent professional literature independently and critically (B7, C6, D6, E6, F6).

1.4. Course content

All lecturers of the compulsory mathematics courses will participate in determining the content of this seminar by proposing the themes for the seminars (according to Regulations on graduate work and the final exam for the university graduate studies at the Department of mathematics, University of Rijeka). Each student will publicly present the theme and submit the work in the written form to the mentor. The work will present the basis for the graduate thesis which will be elaborated in conjunction with the mentor.

1.5. Types of teaching (add an 'X')		
	☐ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☐ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	

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Written exam		Oral exam		Essay		Research	
Project		Continuous assessment		Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester. The total number of points that a student can achieve during classes is 100. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Literature for each seminar will be proposed by the mentor - proponent of the topic.		

1.10. Additional reading

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Vector spaces II	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with the basics of the theory of normed and topological vector spaces. For this purpose it is necessary within the course to:

- define topological vector spaces,
- define normed space and describe typical examples of normed spaces,
- define and analyse local convexity, metrizability and completeness of spaces, analyse linear functionals.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. formulate examples of topological vector spaces (A6, B6, C6, D4, E4, F3),
O2. analyse the connection between linear and topological structure (A6, B6, C6, D4, E5, F3),
O3. formulate examples of normed spaces (A6, B6, C6, D4, E4, F3),
O4. analyse local convexity, metrizability and completeness of spaces (A6, B6, C6, D4, E4, F3),
O5. mathematically prove validity of all procedures and formulas that are used within the course (A6, B6, D4, E5, F3).

1.4. Course content

Topological vector spaces. Normed vector spaces. Local convexity. Metrizability. Completeness. Linear functionals and the Hahn-Banach theorem. Weak topologies. Dual spaces.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☐ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	

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Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
S.Kurepa, Funkcionalna analiza, Školska knjiga, Zagreb, 1984.	12	5

1.10. Additional reading

1. W.Rudin, Functional analysis, McGraw-Hill, 1972.
2. K.Yoshida, Functional analysis, Springer -Verlag, New York, 1985.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	History of mathematics	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	3
	Number of hours (L+P+S)	15 + 0 + 30

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with:
- an introduction to the development of mathematical theories and fundamental branches of mathematics, as well as with work and historical significance of some mathematicians,
- analysis of the ways in which certain branches of mathematics developed.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing this course, the students are expected to:
O1. indicate problems from the everyday life that can be solved using mathematics and point out a relation with other subjects (A7,B5,E5, F5),
O2. present used mathematical knowledge in the historical and mathematical context (A7, B5, C7, D5, E7, F7, G7),
O3. relate and explain causes and effects of the development of mathematical ideas and methods, the role of mathematics in science, art and society (A6,B7),
O4. use different types and forms of communication including information and communication technology (A3,B3, C3, E7, F7),
O5. mathematically prove validity of all procedures and formulas that are used within the course (A7,B5,E5, F5).

1.4. Course content

History of mathematics in the period before ancient Greece. The ancient greek mathematics. Chinese, Arabic, Indian mathematics, mathematics of the New age. Development of probability and statistics, algebra, set theory, mathematical logic. New directions in mathematics.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☐ practicals	☐ laboratory
	☐ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

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Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project		Continuous assessment		Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Ž. Dadić, Razvoj matematike. ideje i metode egzaktnih znanosti u njihovu povijesnom razvoju, Školska knjiga, Zagreb, 1975.	3	5
Ž. Dadić, Povijest ideja i metoda u matematici i fizici, Školska knjiga, Zagreb, 1992.	3	5
L. Hogben, Sve o matematici, Mladost, Zagreb, 1970.	2	5
Z. Šikić, Kako je stvarana novovjekovna matematika, Školska knjiga, Zagreb, 1989.	1	5

1.10. Additional reading

1. Z. Šikić, Filozofija matematike, Školska knjiga, Zagreb, 1995.
2. P.J.Davis, R.Hersh, E.A.Marchisotto, Doživljaj matematike, Tehnička knjiga, Zagreb, 2004.
3. 3.V. Devide, Matematika kroz kulture i epohe, Školska knjiga, Zagreb, 1979.

J. Stillwell, Mathematics and its history, Springer Verlag, 2001.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Popularization of mathematics	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	3
	Number of hours (L+P+S)	15 + 15 + 0

COURSE DESCRIPTION

1.1. Course objectives

Science popularization is an integral part of teacher's and scientist's profession in any subject.
The main course objective is to:

- develop the consciousness of the social context for the science and the need for its popularization,
- train for active professional popularization,
- develop the abilities for planning and conducting activities for popularization of science, scientific topics and scientific research results.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing the course, the students are expected to:

O1. describe and analyse the need and importance of the science popularization, especially mathematics popularization
O2. differentiate and analyse the methods for the science popularization,
O3. describe types of popularization activities and their extent, scope, advantages and disadvantages,
O4. describe the influence of public media on the promotion of scientific activities,
O5. describe and analyse the interaction between scientific institutions and the community (local government, entrepreneurship, education system, civil society, etc.),
O6. design popular science activities and create a plan for the implementation of the activities,,
O7. implement the plan and evaluate the implementation of planned activities as part of field work (e.g. Rijeka Science Festival, Mathematics Evening, Open Day, etc.).

1.4. Course content

An introduction to the popularization of science with an emphasis on the popularization of mathematics and natural sciences. Methods of popularizing science (popular science lecture, workshop for children and young people, popular science exhibition, short interactive demonstration,...). Examples of popular science activities in mathematics and natural sciences. Popular literature and scientific storytelling. Modern technology in the popularization of science. Science and the media. An interdisciplinary approach to the popularization of mathematics. Mathematics in everyday life.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☒ field-based learning	☒ other: consultation

1.6. Students' obligations

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Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an '')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam		Oral exam		Essay		Research	
Project	X	Continuous assessment		Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester. The total number of points that a student can achieve during classes is 100. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
B.Jergović (ur.): Znanost i javnost, Izvori, Zagreb, 2002.	2	5
Znanstveno-popularne radio emisije «Baltazar», CD	2	5
InAMath - An interdisciplinary approach to mathematical education (mod.srce.hr platform)	open access	5

1.10. Additional reading

1. A.Simonić, Znanost najveća avantura i izazov ljudskog roda, Vitagraf, Rijeka, 1999.
2. M. Alley : The Craft of Scientific Presentations: Critical Steps to Succeed and Critical Errors to Avoid. Springer-Verlag, 2002
3. T. Caulton: Hands-On Exhibitions: Managing Interactive Museums and Science Centres (The Heritage, Care-Preservation-Management). Routledge, 1998
4. S.M. Cutlip, A.H. Center, G.M. Broom: Odnosi s javnošću (prijevod 'Effective public relations'). Mate, Zagreb, 2003
5. J. Walker: The Flying Circus of Physics, J.Willey and Sons, New York, 1977.
6. W.R. Wood: FUNtastic Science activities for Kids, McGrow Hill, New York, 1997.
7. Wilson, J. Gregory, S. Miller; S. Earl: Handbook of science communication, Institute of Physics Publishing, 1998

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Methodology of teaching mathematics II	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 0 + 30

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with practical and theoretical aspects of the methods for teaching mathematics in higher grades of elementary schools and in secondary schools. For this purpose it is necessary within the course to:

- introduce the national curriculum for mathematics in higher grades of elementary schools and in secondary schools,
- prepare students for choosing the appropriate methods in the process of teaching mathematics,
- acquaint students with the mathematical knowledge that is necessary for effective teaching of mathematics in higher grades of elementary schools and in secondary schools,
- prepare students for organizing a math teaching class in higher grades of elementary schools and in secondary schools.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. analyse the mathematical curriculum in higher grades of elementary schools and in secondary schools (A6, B6, C5, D6, E5, F5),
O2. differ and valorise different methods of teaching mathematics, especially methods according to the mathematical topics (A7, B6, C6, D6, E7, F7),
O3. organize a mathematics teaching class in higher grades of elementary schools and in secondary schools in accordance with contemporary teaching methods and principles while using suitable teaching strategies (A7, B6, C6, D6, E7, F7),
O4. plan and organize a mathematics teaching class in accordance with contemporary teaching methods and principles while using suitable teaching strategies, with the aim of developing mathematical processes and better understanding of mathematical concepts (A7, B6, C6, D6, E7, F7),
O5. present mathematical content using the teaching aids and facilities (e.g. informational communicational technology) with the proper use of mathematical terminology and language (A6, B6, C6, D6, E7, F7),
O6. independently create teaching materials in mathematics with or without using the advanced tools of ICT (A6, B6, C6, D6, E7, F7),
O7. independently adjust current teaching materials in mathematics for becoming motivational for learning and suitable for accomplishing the planned learning outcomes (A6, B5, C5, D6, E5, F5),
O8. use relevant and recent professional literature independently and critically (A6, B6, C6, D5, E7, F7),
O9. cooperate with colleagues to acquire and develop professional competences, and use the feedback in the aim of improving the teaching process (A6, B6, C5, D6, E7, F7),
O10. use the basic communication principles and techniques of effective professional communication, and express themselves accurately and fluently in spoken and written forms of communication in the

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language of teaching and in the official language (A6, B6, C6, D6, E6, F6).

1.4. Course content

Methods of teaching mathematics (methods according to the source of knowledge and methods according to the mathematical topics). Empirical methods, induction, deduction, analysis and synthesis, generalization, abstraction, concretization, problem-solving methods (heuristics, solving problems), analogy and comparison, special mathematical cases. Methods for specific mathematical topics. In seminars, students will become familiar with the mathematical curriculum in the higher grades of elementary school and in secondary schools. Students will present selected topics in mathematics that are processed in higher grades of elementary school or in secondary schools.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Current textbooks for elementary and secondary schools and teachers' manuals	20	5
Curriculum for the subject of Mathematics for elementary schools and high schools in the Republic of Croatia	https://narodne-novine.nn.hr/clanci/sluzbeni/2019_01_7_146.html	5
Matematika bez suza, ed. Ilona Posokhova, Ostvarenje, Lekenik, 2000.	6	5
Kurnik: Oblici matematičkog mišljenja, Element, Zagreb, 2013.	1	5
Kurnik: Posebne metode rješavanja matematičkih problema, Element, Zagreb, 2010.	2	5
Kurnik: Znanstveni okvir nastave matematike, Element, Zagreb,	2	5

2009.		

1.10. Additional reading

1. Polya,G.: Kako ću riješiti matematički zadatak, Školska knjiga, Zagreb, 1984.
2. XXX: Matematika i škola, časopis za nastavu matematike, Element, Zagreb
3. Available methodical and science popularization journals (printed or online form)

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Seminar III – Foundations of mathematics	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	4
	Number of hours (L+P+S)	0 + 0 + 30

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with the basic concepts of the foundations of mathematics. For this purpose it is necessary within the course to:

- describe the axiomatic method and analyse mathematical-logical-philosophical reasons for its introduction to mathematics,
- describe and analyse Euclidean geometry and its logical shortcomings,
- analyse the problem of "obviously true" statements,
- use visualization in the proof of theorems,
- have knowledge of the paradoxes introduced in mathematics at the beginning of the 20th century and their influence on further development of mathematics,
- describe and analyse Hilbert axiomatic system, Principia Mathematica and Gödel theorems,
- describe the ZFC system of axioms and the theory of categories as an alternative way of foundation of mathematics.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. describe and analyse some axiomatic systems (A6, B7),
O2. relate and explain causes and consequences of the development of mathematical ideas and methods, and the role of mathematics in science, art and society (A6, B7),
O3. use different communication types and forms, including information and communication technology (A6, B6, C6, E7, F7),
O4. use relevant and recent professional literature independently and critically (A6,B7,E6),
O5. express yourself accurately and fluently in spoken and written communication in the correct official language (D6).

1.4. Course content

Axiomatic method and axiomatic system: historical overview. Problems with visualization and intuition, paradoxes, Hilbert's formalism, Frege's logicism. Gödel's results. The ZFC system of axioms and the theory of categories as an alternative way of foundation of mathematics.

1.5. Types of teaching (add an 'X')		
	☐ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network
	☐ practicals	☐ laboratory
	☐ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

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1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam		Essay		Research	
Project		Continuous assessment		Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students are required to attend classes and actively participate in them. The total number of points that a student can achieve during classes is 100. Details will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Frege, G., 1995, Osnove Aritmetike i drugi spisi, Kruzak, Zagreb.	https://www.informationphilosopher.com/solutions/philosophers/frege/Frege_Begriffsschrift.pdf	5

1.10. Additional reading

1. Moore, A.W., 1990, The Infinite, Routledge, London
2. Wittgenstein, L., 1937-44/1972, Remarks on the Foundations of Mathematics, The M.I.T. Press, Cambridge.
3. Benacerraf, P. i Putnam, H., 1983, Philosophy of Mathematics-Selected Readings, second edition, Cambridge University Press, Cambridge.
4. Boolos, G., 1998, Logic, Logic and Logic, Harvard University Press.
5. Nagel, E. i Newman, J.R., 2001, Gödelov dokaz, Kruzak, prevedeno iz Nagel, Newman, 1993, Gödel's Proof, Routledge
6. Brown, J.R., 1999, An Introduction to the World of Proof and Pictures, Routledge

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Statistical practicum	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	15 + 30 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to train students for application of numerical and statistical software packages in mathematical modeling. For that purpose, it is necessary within the course to:

- describe the simulation of outcomes of discrete and continuous random variables and vectors,
- describe the selection of parametric model and execute the adaptation to dana,
- define the point and interval methods for parameter estimation,
- describe the statistical hypothesis testing,
- define the Kolmogorov - Smirnov test,
- define the c2-test,
- describe the estimation of distribution and parameters of statistics by using Monte Carlo method,
- describe methods of comparing two or more populations,
- describe methods of testing hypotheses of independence and correlation tests on two-dimensional statistical features,
- describe methods of estimation and model selection in regression analysis.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. select and understand the parametric model and adapt to data (A7, B7, E4, F5),
O2. apply the Kolmogorov - Smirnov and c2 - test (A7, B7, E4, F5),
O3. estimate the distribution and parameters of statistics by using Monte Carlo method (A7, B7, E4, F5),
O4. apply the methods of comparing two or more populations (A7, B7, E4, F5),
O5. apply the methods of testing hypotheses of independence and correlation tests on the two-dimensional statistical characteristics (A7, B7, E4, F5),
O6. apply the methods of estimation and model selection in regression analysis (A7, B7, E4, F5),
O7. use numerical and statistical software packages in the mathematical modeling (A7, B7, E4, F5),
O8. mathematically prove validity of all procedures and formulas that are used within the course (A7, B7, E4, F5).

1.4. Course content

Simulation of outcomes of discrete and continuous random variables and vectors. Selection of parametric model and adaptation to data. Point and interval methods of parameter estimation. Statistical hypothesis testing. Kolmogorov - Smirnov test. c^2 - test and the strength of a test. Estimation of distributions and parameters of statistics by using Monte Carlo method. Comparison of two populations. Comparison of several populations. Two-dimensional statistical features. Checking the hypothesis of independence. Tests of correlation. Evaluation and selection of models and tests on parameters in regression analysis.

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1.5. Types of teaching (add an 'X')	☒ lectures ☒ seminars and workshops ☒ practicals ☒ distance learning ☐ field-based learning	☒ independent tasks ☒ multimedia and network ☐ laboratory ☐ mentoring work ☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam		Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Ž.Pauše, Uvod u matematičku statistiku, Školska knjiga, Zagreb, 1993.	3	10
D.Nolan, T.Speed, Stat Labs, Springer Verlag, 2001.	1	10

1.10. Additional reading

1. G.K.Bhattacharyya, R.A.Johnson, Statistical Concepts and Methods, John Wiley & Sons, 1977.
2. R.Christensen, Advanced Linear Modeling, Springer Verlag, 2001.
3. G.McPearson, Applying and Interpreting Statistics, Springer Verlag, 2001.
4. J.P.Marques de Sa, Applied Statistics using SPSS, STATISTICA and MATLAB, Springer Verlag, 2003.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Optimization methods in finance	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30+15+15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to demonstrate how recent advances in optimization modeling, algorithms and software can be applied to solve practical problems in computational finance. The focus is on selected topics in finance (such as arbitrage detection, risk-neutral probability measure, portfolio theory and asset management), where the models can be formulated as deterministic or stochastic optimization problems. These problems have various forms (e.g., linear, quadratic, conic, convex, stochastic optimization) and hence various tools, techniques and methods from optimization need to be employed to solve them numerically.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

On completion of this course students will:

O1. be able to define basic terms related to financial mathematics (A2, B2),
O2. be able to list different optimization mehods in finance (A2, B3),
O3. be able to formulate problems in financial mathematics and appreciate their assumptions and limitations (A5, B7, C6),
O4. be able to solve practical problems arising in finance using modern optimization methods and software (C7, D6, E7).

1.4. Course content

Basics of financial mathematics: portfolio selection and asset allocation, pricing and hedging of options, risk management, asset/liability management. Applications of linear and nonlinear programming in finance: asset pricing and arbitrage, risk-neutral probability measure, volatility estimation. Quadratic Optimization and its applications in finance: mean-variance portfolio selection (Markowitz model). Conic Optimization and its applications in finance: capital allocation line and Sharpe ratio. Stochastic Optimization and its apllications in finance: Asset/liability management, stochastic gradient descent, scenario generation

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☐ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

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1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')							
Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
G. Cornuejols and R. Tütüncü, Optimization Methods in Finance, Cambridge University Press. ISBN-10: 0521861705	3	10

1.10. Additional reading

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1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Combinatorial and heuristic optimization	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to address both optimal and heuristic approaches in combinatorial optimization. It should develop an ability to formulate a wide range of management problems that can be solved to optimality by classical combinatorial optimization techniques and the knowledge of alternative solution approaches such as metaheuristics that can find nearly optimal solutions. It also raise an awareness how difficult some practical optimization problems can be.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

On completion of this course students will:

O1. be able to list different mehods of combinatorial optimization (A2, B3);
O2. be able to differ optimal and heuristic methods of combinatorial optimization (i.e. optimal and near-optimal solutions) (A5, B5, C4);
O3. be able to formulate problems in combinatorial optimization and appreciate their assumptions and limitations (A6, B6, C6);
O4. be able to choose appropriate method for solving combinatorial optimization problem using modern optimization methods and software (A7,C7,D6,E7).

1.4. Course content

Optimal and heuristic methods – cutting plane, branch-and-bound, branch-and-cut, Lagrangian relaxation, local search, simulated annealing, tabu search, genetic algorithms, and neural networks. Application on combinatorial optimization problems such as production planning and scheduling, operational management of distribution systems, timetabling, location and layout of facilities, routing and scheduling of vehicles and crews, etc.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

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1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')							
Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam		Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
B. Korte and J. Vygen, Combinatorial Optimization, Theory and Algorithms, Springer, 2012.	3	5
Z. Michalewicz, Genetic Algorithms + Data Structures = Evolution Programs, Springer, 1996.	3	5

1.10. Additional reading

1. G. Cornuejols and R. Tütüncü, Optimization Methods in Finance, Cambridge University Press. ISBN-10: 0521861705

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Stochastic processes	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with basic concepts of theory of stochastic processes. For that purpose, it is necessary within the course to:

- define generating functions and convolutions, and analyze their basic properties,
- describe a simple branching process,
- describe limit distributions and prove the continuity theorem,
- define a simple random walk and analyse its basic properties,
- describe the construction of Markov chains,
- describe the decomposition of state space of Markov chain,
- define transience, recurrence and periodicity,
- describe invariant measures and stationary distributions,
- define and analyse Markov chains with continuous time,
- give the basics of renewal theory.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. use and understand generating functions and their properties in study of stochastic processes (A7, B7, E4, F5),
O2. analyse simple branching processes and their properties (A7, B7, E4, F5),
O3. analyse limit distributions and continuity theorem (A7, B7, E4, F5),
O4. analyse and understand the properties of simple random walks (A7, B7, E4, F5),
O5. carry out and understand the construction of a Markov chain (A7, B7, E4, F5),
O6. describe the decomposition of state space of a Markov chain (A7, B7, E4, F5),
O7. investigate properties of transience, recurrence and periodicity for Markov chains (A7, B7, E4, F5),
O8. analyse Markov chains with continuous time and their properties (A7, B7, E4, F5),
O9. describe basic concepts and results of the renewal theory (A7, B7, E4, F5),
O10. mathematically prove validity of all procedures and formulas that are used within the course (A7, B7, E4, F5).

1.4. Course content

Generating functions. Convolutions. Simple branching process. Limit distributions and continuity theorem. Simple random walk. Stopping times. Construction of Markov chains. Decomposition of the state space. The principle of dissection. Transience and recurrence. Periodicity. Absorption probability. Invariant measures and stationary distributions. Markov chains with continuous time. The backward equation and generating matrix. Laplace transformation method. Poisson process. Renewal processes.

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1.5. Types of teaching (add an 'X')	☒ lectures ☐ seminars and workshops ☒ practicals ☒ distance learning ☐ field-based learning	☒ independent tasks ☒ multimedia and network ☐ laboratory ☐ mentoring work ☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
S.I.Resnick, Adventures in Stochastic Processes, Birkhauser, Boston, 1992.	1	5
D.Nualart, Stochastic Processes, Universitat de Barcelona, 2003.	http://orfeu.mat.ub.es/~nualart/StochProc.pdf	5

1.10. Additional reading

1. W.Feller, An Introduction to Probability Theory and Aplication, J.Wiley, New York, 1966.
2. N.Sarapa, Teorija vjerojatnosti, Školska knjiga, Zagreb, 2002.
3. J.Mališić, Slučajni procesi, teorija i primjena, Građevinska knjiga, Beograd, 1989.
4. J.R.Norris, Markov Chains, Cambridge University Press, 1997.
5. N.U.Prabhu, Stochastic Processes. Basic Theory and Its Application, Worls Scientific Publishing Company, 2008.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Partial differential equations	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with the basics of the theory of partial differential equations. With that purpose the students are presented the following units:

- classification of second order equations: eliptic, hiperbolic and parabolic equations and examples,
- Laplace equation, wave equation and equation of heat conducting,
- Dirichlet's and Green's representation,
- Cauchy's problem,
- Fourier's method, principle of maximum.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. analyse partial differential equations in the sense of their classifications (A7, B7, E4, F5),
O2. differentiate boundary and initial conditions (A7, B7, E4, F5),
O3. apply different theorems in analizing eliptic, hiperbolic and parabolic equations (A7, B7, E4, F5),
O4. solve Laplace equation, analyse Dirichle's and Neumann's problem and apply maximum principle (A7, B7, E4, F5),
O5. apply Poisson's formula and Green's function (A7, B7, E4, F5),
O6. solve the heat equation with different initial-boundary conditions (A7, B7, E4, F5),
O7. solve the wave equation and analyse Cauchy's problem (A7, B7, E4, F5),
O8. apply Fourier's method in solving partial differential equations (A7, B7, E4, F5),
O9. mathematically prove validity of all procedures and formulas that are used within the course (A7, B7, E4, F5).

1.4. Course content

Classification of second order equations. Eliptic, hiperbolic and parabolic equations. Examples. Laplace equation. Dirichle's and Neumann's problem. Green's representation. Green's function. Poisson's formula. Principle of maximum. Potentials. Wave equation. Cauchy's problem. D´Alambert's formula. Initial-boundary problem. Fourier's method. Equation of heat conducting. Principle of maximum. Cauchy's problem. Poisson's formula. Initial-boundary problem. Fourier's method.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

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1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
D. Gilber, S. Trudinger: Eliptic partial differential equations of second order, Springer, 1977.	1	5
L. C. Evans: Partial Differential Equations, American Mathematical Society, 2002.	1	5
H. Levine: Partial Differential Equations, American Mathematical Society, 1997.	1	5

1.10. Additional reading

1. I. Aganović, K. Veselić: Linearne diferencijalne jednadžbe, Element, Zagreb, 1997.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Harmonic analysis	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 0 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students familiar with basic ideas and concepts of harmonic analysis, elements of functional analysis and their application. For that purpose, it is necessary within the course to:

- define Hilbert spaces and analyse their structure and properties,
- determine orthonormal systems in a Hilbert space and analyse their completeness,
- calculate and analyse Fourier series, and compare them to their original functions,
- analyse the consequences of the Banach-Steinhaus theorem and the open mapping theorem related to Fourier series,
- calculate and analyse Fourier transforms,
- analyse the inversion theorem and compare Fourier transform to its original function,
- analyse Plancherel theorem and its consequences,
- compare Fourier transform with other integral transforms: for example Laplace, Mellin, discrete Fourier transform,
- calculate and analyse those other integral transforms.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing this course, the students are expected to:

O1. understand and determine the properties of Hilbert spaces, analyse linear independence, orthogonality, orthonormality, completeness of the sets in them (A7, B7, C7),
O2. calculate and understand Fourier series and analyse their connection with the original functions (A7, B7, C7, F7),
O3. apply and understand the above mentioned theorems about the Banach spaces and analyse their consequences related to Fourier series (A7, B7, C7, F7),
O4. calculate and understand the Fourier transform (A7, B7, C7),
O5. analyse the inversion theorem and compare Fourier transform with the original function (A7, B7, C7, F7),
O6. analyse and apply Plancherel theorem (A7, B7, C7, F7),
O7. calculate and apply other integral transforms (A7, B7, C7).

1.4. Course content

Hilbert space. Orthonormal sets. Fourier series. Banach-Steinhaus theorem. The open mapping theorem. Fourier transform. The inversion theorem. Plancherel teorem and Parseval's formula. Examples of other integral transforms and applications.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☒ seminars and workshops	☒ multimedia and network

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	☐ practicals ☒ distance learning ☐ field-based learning	☐ laboratory ☒ mentoring work ☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam		Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
W. Rudin, Real and Complex Analysis, McGraw-Hill, New York, 1987.	2	5
Anton Deitmar: A First Course in Harmonic Analysis, 2nd edition, Springer, 2005	1	5
George Bachmann, Lawrence Narici, Edward Beckenstein: Fourier and Wavelet Analysis, Springer, New York, 2000	2	5

1.10. Additional reading

1. Allan Pinkus, Samy Zafrany, Fourier Series and Integral Transforms, Cambridge University Press, 1997.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Introduction to combinatorial topology	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	5
	Number of hours (L+P+S)	15 + 15 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with:
- elements of combinatorial topology and counting problems,
- classification convex polytopes according to their „combinatorial properties".

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing the course, the students are expected to:
O1. define basic concepts of combinatorial topology of convex polytopes, apply and understand basic procedures for determining number of faces (A7, B7),
O2. have knowledge of basic theorems in the field of combinatorial topology of convex polytopes and be able to prove them (B7, F4),
O3. draw Schlegel diagrams for 3-polytopes (B5, C7, D7, F7),
O4. independently or in groups examine a given problem (C7, E7, F7, G7).

1.4. Course content

Introduction, convex sets, partially ordered set, polytopes, simplexes, pyramids, bipyramids, Euler's theorem, Dehn-Sommerville equations. Number of faces of simplicial polytopes, lower bound conjecture, number of faces of cyclic polytopes, upper bound conjecture. Lower bound conjecture for simplicial spheres, abstract simplicial complexes, diagrams - Schlegel diagrams, h-vectors, upper bound conjecture for simplicial sphere.
Some properties of h-vectors, McMullen's conditions, Cohen-Macaulay and Gorenstein complexes, monotonicity property of h-vectors.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☐ independent tasks
	☒ seminars and workshops	☐ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☒ other: consultations

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

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Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	
Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment		Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Branko Grunbaum: Convex Polytopes, Springer-Verlag, New York Inc, 2003.	1	10
Darko Veljan: D. Veljan, Kombinatorna i diskretna matematika, Algoritam, Zagreb, 2001.	5	10

1.10. Additional reading

1. Jean Gallier, Notes on Convex sets, Polytopes, Polyhedra, Combinatorial Topology, Voronoi Diagrams and Delaunay Triangulations, Book in Progress (2009), http://www.cis.upenn.edu/~cis610/convex67.pdf

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Seminar of applied discrete mathematics	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	5
	Number of hours (L+P+S)	0 + 30 + 15

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with some possibilities of the applied Discrete mathematics through the acquaintance of the real system in the economy and some problem from the system which can be solved using Discrete mathematics. In addition, the course objective is to develop an ability of mathematical modelling of such problems, and communication and presentation skills while presenting problems, their models and solutions.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing the course, the students are expected to:

O1. express themselves accurately and fluently in speech communication in the language of teaching and the correct official language (D6),

O2. use a variety of communication means and forms (D5),

O3. mathematically model a problem of the economy using Discrete mathematics (A6, B6, C4, D5, E4, F4),

O4. apply and understand the methods of Discrete mathematics while modeling and simulating real problems, and analyse obtained results (A6, B5, C5, D6, E4, F5).

1.4. Course content

Seminar is based on the previously attended courses in the field of Discrete mathematics and represents their expansion. The content of the seminar is the application of Discrete mathematics in problems related to the management of business entities (e.g. optimization of business/production processes).

1.5. Types of teaching (add an 'X')		
	☐ lectures	☒ independent tasks
	☒ seminars and workshops	☐ multimedia and network
	☐ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☒ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper	X	Experimental work	

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Written exam		Oral exam		Essay		Research	X
Project		Continuous assessment		Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Seminar is based on the courses in the field of Discrete mathematics and represents their expansion, and therefore, required literature, depending on the topic of a seminar, is based on the literature of the previously attended courses.		

1.10. Additional reading

Recommended literature will be given by the mentor of the seminar paper, and it will depend on the topic of a given problem.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Measure and integral	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The main course objective is to get students acquainted with some possibilities of the applied Discrete mathematics through the acquaintance of the real system in the economy and some problem from the system which can be solved using Discrete mathematics. In addition, the course objective is to develop an ability of mathematical modelling of such problems, and communication and presentation skills while presenting problems, their models and solutions.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

After completing the course, the students are expected to:

O1. express themselves accurately and fluently in speech communication in the language of teaching and the correct official language (D6),

O2. use a variety of communication means and forms (D5),

O3. mathematically model a problem of the economy using Discrete mathematics (A6, B6, C4, D5, E4, F4),

O4. apply and understand the methods of Discrete mathematics while modeling and simulating real problems, and analyse obtained results (A6, B5, C5, D6, E4, F5).

1.4. Course content

Seminar is based on the previously attended courses in the field of Discrete mathematics and represents their expansion. The content of the seminar is the application of Discrete mathematics in problems related to the management of business entities (e.g. optimization of business/production processes).

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☐ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

Course attendance	X	Activity / Participation		Seminar paper		Experimental work	

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Written exam	X	Oral exam	X	Essay		Research	
Project		Continuous assessment	X	Report		Practice	
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Sibe Mardešić: Matematička analiza II, Školska knjiga , Zagreb, 1977	3	5
Donald L.Cohn: Measure theory, Birkhäuser Boston, 1994	2	5

1.10. Additional reading

1. P.Halmos: Measure theory, Springer-Verlag, New York, 1974
2. N.Antonić, M.Vrdoljak: Mjera i integral, PMF-Matematički odjel, Zagreb, 2001

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.

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GENERAL INFORMATION		
Course coordinator		
Course title	Neural networks	
Study programme	Discrete mathematics and its applications	
Course status	Elective	
Year	2.	
ECTS credits and form of instruction	ECTS credits	6
	Number of hours (L+P+S)	30 + 30 + 0

COURSE DESCRIPTION

1.1. Course objectives

The goal of the course is to familiarize students with concepts from the theory and application of artificial neural networks. For this purpose, the course will:

- introduce the basic concepts related to neural networks,
- describe the basic architecture of neural networks,
- describe basic and advanced algorithms based on neural networks,
- introduce and actively apply a programming language in solving typical problems in this area.

1.2. Course enrolment requirements

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1.3. Expected course learning outcomes

After completing the course, students will be able to:
O1. define and understand the basic concepts of neural networks and their applications (A5, B5, C5, E3, F4),
O2. recognize the specifics of practical problems that can be solved using neural networks (A5, B5, C5, E3, F4),
O3. relate and apply numerous mathematical models, usually from the fields of mathematical analysis, graph theory, probability and statistics as well as optimization theory, used in neural network-based algorithms and techniques (A5, B6, C6, E4, F4, G4),
O4. use a programming language when working with neural networks (A5, B6, C6, E4, F4, G4),
O5. evaluate the efficiency of solutions obtained on the basis of neural networks (A5, B6, C6, E4, F4, G4).

1.4. Course content

Neuron and biological neural networks. Neuron models. Perceptron. Artificial neural networks. Architecture of neural networks. Types of neural networks. Application of neural networks to different tasks and problems. Regularization and optimization methods.

1.5. Types of teaching (add an 'X')		
	☒ lectures	☒ independent tasks
	☐ seminars and workshops	☒ multimedia and network
	☒ practicals	☐ laboratory
	☒ distance learning	☒ mentoring work
	☐ field-based learning	☐ other _____

1.6. Students' obligations

Students are required to attend classes and actively participate in them. They are required to achieve a certain number of points during the semester and to pass the final exam (details will be described in the course syllabus).

1.7. Monitoring students' work (indicate the relevant form of monitoring by adding an 'X')

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Course attendance	X	Activity / Participation		Seminar paper		Experimental work	
Written exam		Oral exam	X	Essay		Research	X
Project		Continuous assessment	X	Report		Practice	X
Portfolio							

1.8. Assessment and evaluation of student work during classes and at the final exam

Students' work will be evaluated and assessed during the semester (e.g. preliminary exams, tests, seminars, online tests, homework etc.) and on the final exam. A detailed elaboration of monitoring and evaluation of students' work will be described in the course syllabus.

1.9. Essential reading and the number of copies provided in relation to the current number of course participants

Title	Number of copies	Number of students
Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer 2007.,	1	5
Michael Negnevitsky, Artificial Intelligence, A Guide to Intelligent Systems, 2011.	2	5

1.10. Additional reading

1. S. Haykin, Neural Networks, 2nd Ed., Prentice Hall, 1998.
2. J. A. Anderson, An Introduction to Neural Networks, MIT Press., 1995.

1.11. Quality monitoring methods ensuring the acquisition of expected knowledge, skills and competencies

At the end of the semester, an anonymous survey will be conducted in which students will evaluate the quality of the classes held. After the end of the semester, an analysis of the performance of the students in the exams held in that semester will be conducted.