PROGRAM OF STUDIES

FACULTY OF PURE AND APPLIED MATHEMATICS
MAIN FIELD OF STUDY: **APPLIED MATHEMATICS**
BRANCH OF SCIENCE: **NATURAL SCIENCES**
DISCIPLINES: **MATHEMATICS**

EDUCATION LEVEL: **second-level studies**
FORM OF STUDIES: **full-time studies**
PROFILE: **general academic**
LANGUAGE OF STUDY: **English**

Content:

1. Assumed learning outcomes – attachment no. 1 to the program of studies
2. Program of studies description – attachment no. 2 to the program of studies

Resolution no. … of the Senate of Wroclaw University of Science and Technology

In effect since 2023/2024

Attachment no. 1. to the Program of Studies

ASSUMED LEARNING OUTCOMES

FACULTY OF PURE AND APPLIED MATHEMATICS
MAIN FIELD OF STUDY: APPLIED MATHEMATICS
EDUCATION LEVEL: second-level studies
PROFILE: general academic

<u>Location of the main-field-of study:</u>

Branch of science: NATURAL SCIENCES

Discipline / disciplines (for several disciplines, please indicate the major discipline): MATHEMATICS

<u>Explanation of the markings:</u>
P7U – universal second degree characteristics corresponding to education at the second-level studies - 7 PRK level *
P7S – second degree characteristics corresponding to education at the second-level studies - 7 PRK level *

W - category "knowledge"
U - category "skills"
K-cathegory “social competences”

… _inż. – learning outcomes related to the engineer competences

KAMAN_W1, ... - main-field-of study learning outcomes related to the category "knowledge"
KAMAN_U1, ... - main-field-of study learning outcomes related to the category "skills"
KAMAN_K1, ... - main-field-of study learning outcomes related to the category "social competences"

* delete as applicable

Main field of study learning outcomes	**Description of learning outcomes for the main-field-of study** **Applied Mathematics** After completion of studies, the graduate:	Reference to PRK characteristics		
		Universal first degree characteristics (U)	Second degree characteristics typical for qualifications obtained in higher education (S)	
			Characteristics for qualifications on 7 levels of PRK	Characteristics for qualifications on 6 and 7 levels of PRK, enabling acquiring engineering competences
KNOWLEDGE (W)				
KAMAN_W01	Has an in-depth knowledge of the basic branches of mathematics	P7U_W	P7S_WG	
KAMAN_W02	Understands well the role and importance of the construction of mathematical reasoning	P7U_W	P7S_WG	
KAMAN_W03	Knows the most important theorems and hypotheses from the main branches of mathematics	P7U_W	P7S_WG	
KAMAN_W04	Has in-depth knowledge in a selected area of theoretical or applied mathematics	P7U_W	P7S_WG	
KAMAN_W05	Has in-depth knowledge in a selected area of mathematics: knows most of the classical definitions and theorems and their proofs	P7U_W	P7S_WG	
KAMAN_W06	Is able to understand the formulation of issues remaining in the research stage	P7U_W	P7S_WG	
KAMAN_W07	Knows the interrelationship of the issues of the selected field with other branches of theoretical and applied mathematics	P7U_W	P7S_WG	

KAMAN_W08	Knows advanced computing techniques, supporting the work of mathematician and understands their limitations, oriented to the directions of their development	P7U_W	P7S_WG, P7S_WG	
KAMAN_W09	Knows the basics of stochastic modeling in financial and actuarial mathematics or in the natural sciences, especially physics, chemistry or biology	P7U_W	P7S_WG	
KAMAN_W10	Knows the methods used to find approximate solutions to mathematical problems (for example, differential equations) posed by applied fields (e.g., industrial technology, management, etc.) and the problems associated with the use of some of these methods	P7U_W	P7S_WK, P7S_WG	
KAMAN_W11	Knows the mathematical foundations of information theory, algorithm theory and cryptography and their practical applications in programming and computer science in the broadest sense, among others	P7U_W	P7S_WG	
KAMAN_W12	Is well acquainted with at least one software package for symbolic calculations and one package for statistical data processing	P7U_W	P7S_WG	
KAMAN_W13	Speaks foreign language at a level sufficient to read current professional literature	P7U_W	P7S_WG	
KAMAN_W14	Knows the principles of health and safety at work sufficiently to work independently in the profession of mathematician	P7U_W	P7S_WK	
KAMAN_W15	knows the general principles and theorems of the theoretical approach to statistical inference and methods for determining optimal decision functions	P7U_W	P7S_WG	
KAMAN_W16	knows advanced methods of estimation and hypothesis testing in statistical parametric and nonparametric models, for discrete	P7U_W	P7S_WG	

	and continuous data, in general linear models and for some classes of stochastic processes			
KAMAN_W17	knows methods of time series forecasting	P7U_W	P7S_WG	
KAMAN_W18	knows the methods of computer stochastic modeling in mathematical statistics	P7U_W	P7S_WG	
KAMAN_W19_inż	Has knowledge necessary to understand the non-technical conditions of engineering work activities	P7U_W	P7S_WG	P7S_WG_inż
KAMAN_W20_inż	Knows the typical technologies with which to apply mathematical methods to engineering problems	P7U_W	P7S_WG	P7S_WG_inż
KAMAN_W21_inż	knows methods used to solve simple engineering tasks using mathematical methods	P7U_W	P7S_WG	P7S_WG_inż
KAMAN_W22_inż	Has knowledge of the life cycle of technical equipment and systems	P7U_W	P7S_WG	P7S_WG_inż
KAMAN_W23	Has knowledge of management and business operations and copyrights	P7U_W	P7S_WK	P7S_WK_inż
SKILLS (U)				
KAMAN_U01	Has the ability to construct mathematical reasoning: proving theorems, as well as refuting hypotheses through construction and selection of counter-examples	P7U_U	P7S_UW	
KAMAN_U02	Has the ability to express mathematical content orally and in writing, in mathematical texts of different nature	P7U_U	P7S_UW	
KAMAN_U03	Has the ability to check the correctness of inferences in building formal proofs in mathematical problems, perceives formal structures related to the basic branches	P7U_U	P7S_UW	

	of mathematics and understands the importance of their properties			
KAMAN_U04	In mathematical problems, perceives formal structures related to branches of mathematics and understands the importance of their properties	P7U_U	P7S_UW	
KAMAN_U05	freely uses the tools of analysis, including differential and integral calculus, elements of complex and Fourier analysis	P7U_U	P7S_UW	
KAMAN_U06	Is familiar with methods of solving classical ordinary and partial differential equations, is able to apply them to typical practical problems	P7U_U	P7S_UW	
KAMAN_U07	Can apply the concepts of measure theory to typical theoretical and practical problems	P7U_U	P7S_UW	
KAMAN_U08	Has the ability to recognize topological structures in mathematical objects found, for example, in geometry or mathematical analysis; can use topological properties of sets, functions and transformations	P7U_U	P7S_UW	
KAMAN_U09	Uses the language and methods of functional analysis in problems of mathematical analysis and its applications	P7U_U	P7S_UW	
KAMAN_U10	Is able to apply algebraic methods (with emphasis on linear algebra) in solving problems from different branches of mathematics and practical tasks	P7U_U	P7S_UW	
KAMAN_U11	knows various probabilistic distributions and their properties; can apply them to practical problems	P7U_U	P7S_UW	

KAMAN_U12	is able, at an advanced level and including modern mathematics, to apply, discuss and present orally and in writing, the methods of at least one selected branch of mathematics: mathematical analysis and functional analysis, the theory of differential equations and dynamic systems, algebra and number theory, geometry and topology, probability calculus and statistics, discrete mathematics and graph theory, logic and multiplicity theory; he is able to plan his further development in the selected field	P7U_U	P7S_UK, P7S_UU, P7S_UW	
KAMAN_U13	In the selected field is able to carry out proofs, in which he also applies, if necessary, tools from other branches of mathematics, is able to assess the correctness of calculations and experimental results	P7U_U	P7S_UK, P7S_UW	
KAMAN_U14	Is able to identify his interests and develop them; in particular, he is able to direct the work of a team; he is able to establish contact with specialists in his field, such as understanding their lectures intended for young mathematicians	P7U_U	P7S_UK, P7S_UO, P7S_UU	
KAMAN_U15	Can construct mathematical models, used in specific advanced applications of mathematics	P7U_U	P7S_UW	
KAMAN_U16	Understands the mathematical basis for the analysis of algorithms and computational processes	P7U_U	P7S_UW	
KAMAN_U17	Can construct algorithms with good numerical properties for solving typical and atypical mathematical problems	P7U_U	P7S_UW	
KAMAN_U18	Knows how to use methods of computer-aided theorem proving and logical support for program verification and specification	P7U_U	P7S_UW	
KAMAN_U19	Can determine optimal statistical decisions in complex models of mathematical statistics	P7U_U	P7S_UW	

KAMAN_U20	Knows how to use computer stochastic modeling methods in mathematical statistics	P7U_U	P7S_UW	
KAMAN_U21	Can use professional statistical packages for statistical analysis	P7U_U	P7S_UW	
KAMAN_U22	Has language skills in the fields of science and scientific disciplines appropriate to the studied field of study	P7U_U	P7S_UK	
KAMAN_U23	Can plan and carry out computer simulations and simple experiments, and interpret the results and draw conclusions	P7U_U	P7S_UW	
KAMAN_U24	can use analytical and simulation methods to formulate and solve engineering tasks	P7U_U	P7S_UW	P7S_UW_inż
KAMAN_U25	Is able to use mathematical methods and evaluate their usefulness in solving simple engineering tasks	P7U_U	P7S_UW	P7S_UW_inż
KAMAN_U26	Can - when solving engineering tasks - recognize their non-technical aspects	P7U_U	P7S_UW	P7S_UW_inż
KAMAN_U27	Is able to make a preliminary economic analysis of the engineering activities undertaken	P7U_U	P7S_UW	P7S_UW_inż
KAMAN_U28	Is able to make a critical analysis of how of an existing technical solution	P7U_U	P7S_UW	P7S_UW_inż
KAMAN_U29	Can identify and formulate specifications for simple engineering tasks	P7U_U	P7S_UW	P7S_UW_inż
KAMAN_U30	Can simulate a process reflecting the behavior observed in engineering problems, using appropriate methods and tools	P7U_U	P7S_UW	P7S_UW_inż
SOCIAL COMPETENCES (K)				
KAMAN_K01	knows the limitations of his own knowledge and understands the need for further education	P7U_K	P7S_KK, P7S_KR,	

KAMAN_K02	Can accurately formulate questions to deepen his own understanding of a topic or to find missing elements of reasoning	P7U_K		
KAMAN_K03	Is able to work as a team; understands the need to work systematically on any projects that are long-term in nature	P7U_K	P7S_KR	
KAMAN_K04	Understands and appreciates the importance of intellectual honesty in his own and others' actions; acts ethically	P7U_K	P7S_KK	
KAMAN_K05	Understands the need for popular presentation of selected achievements of higher mathematics to laymen	P7U_K	P7S_KO	
KAMAN_K06	Can independently search for information in the literature, including in foreign languages	P7U_K	P7S_KR	
KAMAN_K07	Is able to form opinions on mathematical issues	P7U_K	P7S_KK	
KAMAN_K08	Has a need to learn about other fields of science, including in humanities subjects	P7U_K	P7S_KK	
KAMAN_K09	Takes care to maintain physical fitness and condition useful for professional work	P7U_K	P7S_KR	
KAMAN_K10	Is aware of the importance and understands the non-technical aspects and consequences of engineering activities	P7U_K	P7S_KO	P7S_KO_inż
KAMAN_K11	Can think and act in an entrepreneurial manner	P7U_K	P7S_KO	

*delete as applicable

Attachment no. 2. to the Program of Studies

DESCRIPTION OF THE PROGRAM OF STUDIES

Main field of study: APPLIED MATHEMATICS

Profile general academic

Level of studies: second-level studies**.**

Form of studies: full-time studies

1. General description

*1.1 Number of semesters: **3***	*1.2 Total number of ECTS points necessary to complete studies at a given level: **90***
*1.3 Total number of hours:**825***	*1.4 Prerequisites (particularly for second-level studies):* Fulfillment of additional admissions requirements (completion of a bachelor's degree with the required degree and in an acceptable field of study), as specified in the document "Conditions and Procedures for Recruitment to Higher Education at Wrocław University of Technology" for a given academic year.
1.5 Upon completion of studies graduate obtains professional degree of: magister inżynier	1.6 Graduate profile, employability: The graduate has an in-depth knowledge of mathematics and its applications. He has the ability to: (1) construct mathematical reasoning, test the veracity of mathematical hypotheses, present mathematical content in speech and writing; (2) build mathematical models necessary for mathematical applications; (3) use advanced computer tools in

	solving theoretical and practical mathematical problems; (4) independently expand mathematical knowledge in the field of current research results. Graduates are prepared to: (1) to work independently in institutions using mathematical methods for data processing and analysis; (2) to teach mathematics in schools at all levels - after completing a teaching specialty (in accordance with the relevant regulation of the Minister of Higher Education on standards of teacher education); (3) to continue their education in doctoral school or postgraduate studies.
1.7 Possibility of continuing studies: Doctoral School, Postgraduate studies	*1.8 Indicate connection with University's mission and its development strategy:* *Applied mathematics has been and continues to be one of the main research interests of the Faculty of Mathematics at Wroclaw University of Technology. The education in financial, insurance and industrial mathematics at the Faculty of Mathematics of Wroclaw University of Technology is unique in the country and is in the mainstream of contemporary global trends.*

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

2. **Detailed description**

2.1 Total number of learning outcomes in the program of study:

W (knowledge) =. 35 U (skills) = .42 K (competences) = 19, W + U + K = 96.

2.2 For the main field of study assigned to more than one discipline - the number of learning outcomes assigned to the discipline:

not applicable (single discipline)

2.3 For the main field of study assigned to more than one discipline - percentage share of the number of ECTS points for each discipline:

100% (mathematics)

2.4a. For the general academic profile of the main field of study – the number of ECTS points assigned to the classes related to the University's academic activity in the discipline or disciplines to which the main field of study is assigned – DN (must be greater than 50% of the total number of ECTS points from 1.2)

48 ECTS

2.4b. For the practical profile of the main field of study - the number of ECTS points assigned to the classes shaping practical skills (must be greater than 50% of the total number of ECTS points from 1.2)

not applicable

2.5 Concise analysis of compliance of the assumed learning outcomes with the needs of the labor market

The assumed learning outcomes respond to contemporary labor market demand in the context of mathematics applications. More and more industrial companies are establishing their own research centers, where processes related to a particular industry are analyzed.

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[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
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Without knowledge of mathematical methods and tools, such analysis is not possible. The Applied Mathematics responds to market demand in this regard. In addition, mathematical methods are used in every industry (finance, telecommunications, mining, etc). The ability to apply these methods, along with a strong programming foundation, gives graduates the chance to find a job that will give them the opportunity find new experients.

2.6. The total number of ECTS points that a student must obtain in classes requiring direct participation of academic teachers or other persons conducting classes and students (enter the sum of ECTS points for courses / groups of courses marked with the BU[1] code)

47 ECTS

2.7. Total number of ECTS points, which student has to obtain from basic sciences classes

Number of ECTS points for obligatory subjects	6
Number of ECTS points for optional subjects	0
Total number of ECTS points	6

2.8. Total number of ECTS points, which student has to obtain from practical classes, including project and laboratory classes (enter total number of ECTS points for courses/group of courses denoted with code P)

Number of ECTS points for obligatory subjects	12
Number of ECTS points for optional subjects	32
Total number of ECTS points	44

2.9. Minimum number of ECTS points, which student has to obtain doing education blocks offered as part of University-wide classes or other main field of study (enter number of ECTS points for courses/groups of courses denoted with code O)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
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8 ECTS

2.10. Total number of ECTS points, which student may obtain doing optional blocks (min. 30% of total number of ECTS points)

38 ECTS

3. Description of the process leading to learning outcomes acquisition:

Learning outcomes will be obtained during students' participation in lectures, exercises, laboratories and seminars, as well as through the implementation of projects and individual work. Verification of the attainment of learning outcomes will take place through colloquia, examinations, paper tests and work in classes organized by the University.

4. List of education blocks:

4.1. List of obligatory blocks:

4.1.2 List of basic sciences blocks

4.1.2.2 *Physics* block

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Partial differential equations with applications in physics and industry **(GK)**	2	2				KAMAN_W03 KAMAN_W07 KAMAN_U06 KAMAN_U08 KAMAN_U09 KAMAN_U15 KAMAN_U16 KAMAN_U24 KAMAN_U25 KAMAN_K01 KAMAN_K06	60	180	6	6	3	T	E (w)		DN	P(2)	PD, S(MIC)
		Total							60	180	6	6	3					2	

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
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Altogether for basic sciences blocks

Total number of hours					Total number of ZZU hours	Total number of CNPS hours	Total number of ECTS points	Total number of ECTS points for DN classes[5]	Number of ECTS points for BU classes[1]
lec	cl	lab	pr	sem					
2	2				60	180	6	6	3

4.1.3 List of the main field of study blocks

4.1.3.1 *Obligatory main field of study* blocks

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Economathematics **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_W16 KAMAN_W17 KAMAN_W18 KAMAN_U15 KAMAN_U20 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	E (w)		DN	P(2)	S (FAM)
		Life Insurance Models **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_W22 KAMAN_U15 KAMAN_U24 KAMAN_U25	60	150	5	5	3	T	E(w)		DN	P(2)	S (FAM)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_K06											
		Optimization theory **(GK)**	2	2				KAMAN_W01 KAMAN _W02 KAMAN _W03 KAMAN _W06 KAMAN _W07 KAMAN _W08 KAMAN_W10 KAMAN_W15 KAMAN_U01 KAMAN_U11 KAMAN_U19 KAMAN_U24 KAMAN_U25 KAMAN_U29 KAMAN_K01 KAMAN_K02 KAMAN_K06 KAMAN_K07 KAMAN_K03 KAMAN_K04 KAMAN_K05	60	180	6	6	3	T	E(w)		DN	P(2)	S (MSO)
		Agent-based modelling of complex systems **(GK)**	2		2			KAMAN_W08, KAMAN_W09 KAMAN_W11 KAMAN_U23 KAMAN_U17 KAMAN_U18 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (DAT)
		Total							240	630	21	21	12					8	

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

Altogether (for main field of study blocks):

Total number of hours					Total number of ZZU hours	Total number of CNPS hours	Total number of ECTS points	Total number of ECTS points for DN classes[5]	Number of ECTS points for BU classes[1]
lec	cl	lab	pr	sem					
8	6	2			240	630	21	21	12

4.2 List of optional blocks

4.2.1 List of general education blocks

4.2.1.1 Liberal-managerial subjects blocks

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Social course	2					KAMAN_W19 KAMAN_W23, KAMAN_U22 KAMAN_U27 KAMAN_K08, KAMAN_K10, KAMAN_K11	30	75	3		3	T		O			KO
		/Humanities course	2					KAMAN_W19, KAMAN_W23, KAMAN_U22 KAMAN_U27 KAMAN_K08,	15	50	2		2	T		O			KO

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
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								KAMAN _K10, KAMAN _K11											
		Total	4						45	125	5		5						

4.2.1.2 ***Foreign languages*** **block** *(min. .... ECTS points):*

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Foreign language		1				KAMAN_W13, KAMAN_K06	15	30	1		1	T		O			KO
		Foreign language		3				KAMAN_W13, KAMAN_K06	45	60	2		2	T		O			KO
		Total		4					60	90	3		3						

Altogether for general education blocks:

Total number of hours					Total number of ZZU hours	Total number of CNPS hours	Total number of ECTS points	Total number of ECTS points for DN classes[5]	Number of ECTS points for BU classes[1]
lec	cl	lab	pr	sem					
4	4				105	215	8		8

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

4.2.2 List of basic sciences blocks

4.2.2.1 *Mathematics* block

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
1		Financial risk management **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (FAM)
2		Computational Finance **(GK)**	2		2			KAMAN_W04, KAMAN_W09 KAMAN_W08, KAMAN_W10 KAMAN_U15, KAMAN_U16, KAMAN_U17, KAMAN_U23 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (FAM, Dat)
3		Insurance models for industry **(GK)**	2		2			KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (FAM)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

4		Reserves in life and non-life insurance **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (FAM)
5		Risk management in insurance **(GK)**	2			2		KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (FAM)
6		Numerical methods in differential equations **(GK)**	2		2			KAMAN_W03 KAMAN_W10 KAMAN_U15, KAMAN_U24 KAMAN_U25 KAMAN_U28 KAMAN_U29 KAMAN_U16 KAMAN_K06 KAMAN_K01	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC)
7		Introduction to applied fluid dynamics **(GK)**	2			2		KAMAN_W03 KAMAN_W06 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

8		Perturbation Methods **(GK)**	2		2			KAMAN_W04 KAMAN_W10 KAMAN_U15 KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC)
9		Applied Functional analysis **(GK)**	2		2			KAMAN_W03 KAMAN_W07 KAMAN_U09 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC)
10		Nonlinear Methods **(GK)**	2		2			KAMAN_W04 KAMAN_W10 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC)
11		Introduction to Inverse Problems **(GK)**	2		2			KAMAN_W04, KAMAN_W06, KAMAN_W07, KAMAN_W13 KAMAN_U04, KAMAN_U05, KAMAN_U06, KAMAN_U09 KAMAN_U24 KAMAN_U25 KAMAN_W08, KAMAN_W10, KAMAN_W12 KAMAN_U16, KAMAN_U17 KAMAN_K05, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC, MSO)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_K03, KAMAN_K04											
12		Free boundary problems **(GK)**	2	2				KAMAN_W03 KAMAN_W10 KAMAN_U15, KAMAN_U24 KAMAN_U25 KAMAN_U28, KAMAN_U29 KAMAN_U16 KAMAN_K06 KAMAN_K01	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MIC)
13		Diffusion processes on complex networks **(GK)**	2		2			KAMAN_W04, KAMAN_W09 KAMAN_U23 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (Dat)
14		Analysis of unstructured data **(GK)**	2			2		KAMAN_W12 KAMAN_U21, KAMAN_U20 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (Dat)
15		Advanced Applications of Statistical Packages **(GK)**	2		2			KAMAN_W02, KAMAN_W04, KAMAN_W08, KAMAN_W16 KAMAN_W13	60	150	5	5	3	T	Z(w)		DN	P(2)	S (Dat)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_W12, KAMAN_W18 KAMAN_U11, KAMAN_U15, KAMAN_U20, KAMAN_U21 KAMAN_U24 KAMAN_U25 KAMAN_U02, KAMAN_U12 KAMAN_K02 KAMAN_K05											
16		Computer simulations of stochastic processes **(GK)**	2		2			KAMAN_W04, KAMAN_W05 KAMAN_W09 KAMAN_U13, KAMAN_U17, KAMAN_U23, KAMAN_U24 KAMAN_U25 KAMAN_U30 KAMAN_K03, KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (Dat, MSO)
17		Estimation theory **(GK)**	2		2			KAMAN_W04, KAMAN_W15, KAMAN_W16, KAMAN_W18 KAMAN_W13 KAMAN_W12, KAMAN_U11, KAMAN_U12 KAMAN_U20, KAMAN_U21 KAMAN_U24	60	150	5	5	3	T	Z(w)		DN	P(2)	S (Dat)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_U25 KAMAN_U02, KAMAN_K06 KAMAN_K01											
18		Mathematical Image Processing **(GK)**	2		2			KAMAN_W04, KAMAN_W06, KAMAN_W07, KAMAN_W13 KAMAN_U04, KAMAN_U05, KAMAN_U06, KAMAN_U09 KAMAN_U16, KAMAN_U17 KAMAN_U24 KAMAN_U25 KAMAN_K05, KAMAN_K06 KAMAN_K03, KAMAN_K04	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MSO)
19		Queues and Communication Networks **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MSO)
20		Advanced Topics in Dynamic Games **(GK)**	2	2				KAMAN_W01 KAMAN _W02 KAMAN _W12 KAMAN _W13 KAMAN _W17	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MSO)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN _U04, KAMAN _U05, KAMAN _U07, KAMAN _U08, KAMAN _U10, KAMAN _U13, KAMAN _U18, KAMAN _U23, KAMAN_U24 KAMAN_U25 KAMAN _U26, KAMAN _U27 KAMAN _K01, KAMAN _K04, KAMAN _K05, KAMAN _K07											
21		Operations Research **(GK)**	2		2			KAMAN_W04 KAMAN_W08, KAMAN_W11, KAMAN_W21 KAMAN_U10 KAMAN_U15, KAMAN_U24 KAMAN_U25 KAMAN_K05	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MSO)
22		Optimal control **(GK)**	2		2			KAMAN_W01, KAMAN_W02, KAMAN_W03, KAMAN_W06, KAMAN_W07, KAMAN_W08, KAMAN_W10	60	150	5	5	3	T	Z(w)		DN	P(2)	S (MSO)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_U01, KAMAN_U02, KAMAN_U03, KAMAN_U15, KAMAN_U16, KAMAN_U17, KAMAN_U18, KAMAN_U19 KAMAN_U24 KAMAN_U25 KAMAN_K01, KAMAN_K02, KAMAN_K03, KAMAN_K04, KAMAN_K05, KAMAN_K06 KAMAN_K07											
23		Introduction to big data analytics (GK)	2		2			KAMAN_W12 KAMAN_U21, KAMAN_U20 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (Dat)
24		Data Mining (GK)	2		2			KAMAN_W12 KAMAN_U21, KAMAN_U20 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (DAT)
25		Machine Learning (GK)	2		2			KAMAN_W12 KAMAN_U21, KAMAN_U20 KAMAN_U24 KAMAN_U25	60	150	5	5	3	T	Z(w)		DN	P(2)	S (DAT)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_K02, KAMAN_K06											
26		Introduction to Compressed Sensing (GK)	2		2			KAMAN_W12 KAMAN_U21, KAMAN_U20 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	Z(w)		DN	P(2)	S (DAT, MSO)
		Razem							1560	3900	130	130	78					52	

4.3 Training block - concerning principles of training crediting – "Diploma seminar"

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Diploma Seminar					2	KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	30	60	2	2	1	T	Z		DN	P(2)	S
		Total					2		60	750	2	2	6					2	

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

4.4 „Diploma dissertation” block (*if it is foreseen at first level studies)*

Type of diploma dissertation	Licencjat / inżynier / magister / magister inżynier*	
Number of diploma dissertation semesters	**Number of ECTS points**	**Code**
1	28	
Character of diploma dissertation		
Literature survey, project, computer program, etc.		
Number of BU[1] ECTS points	8	

5. Ways of verifying assumed learning outcomes

Type of classes	Ways of verifying assumed learning outcomes
lecture	exam, colloquium
class	paper, test, test, test
laboratory	entrance exam, lab report, report
project	project defense, report
seminar	participation in discussion, presentation of the topic, essay
training	practice report
diploma dissertation	prepared thesis

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

6. Range of diploma examination

The diploma exam is an oral examination that tests the knowledge acquired by the student in the course of study, within the scope given in the program of studies and course charters. The student is asked at least three questions, at least two of which are from compulsory directional subjects and at least one from the subject assigned to the specialty module chosen by the student.

The questions asked to the student must not go beyond the material of the subjects completed by that student in the course of education.

7. Requirements concerning deadlines for crediting courses/groups of courses for all courses in particular blocks

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8. Plan of studies (attachment no. 4)

Approved by faculty student government legislative body:

....	....
Date	name and surname, signature of student representative
....	....
Date	Dean's signature

*delete as appropriate

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes

[2]Traditional – enter T, remote – enter Z

[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)

[4]University-wide course /group of courses – enter O

[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned

[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses

[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

Attachment no. 3 to Program of Studies

PLAN OF STUDIES

FACULTY OF PURE AND APPLIED MATHEMATICS

MAIN FIELD OF STUDY: APPLIED MATHEMATICS

EDUCATION LEVEL: second-level studies

FORM OF STUDIES: full-time studies

PROFILE: general academic

SPECIALIZATION:

Financial and Actuarial Mathematics, Mathematics for Industry and Commerce, Data Engineering, Modelling, Simulation and Optimization

LANGUAGE OF STUDY: English

In effect since 2023/2024

1. Set of obligatory and optional courses and groups of courses in semestral arrangement

Semester 1

Obligatory courses / groups of courses Number of ECTS points 16

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Economathematics **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_W16 KAMAN_W17 KAMAN_W18 KAMAN_U15 KAMAN_U20 KAMAN_U24 KAMAN_U25KAMAN_K06	60	150	5	5	3	T	E (w)		DN	P(2)	S (FAM)
		Partial differential equations with applications in physics and industry **(GK)**	2	2				KAMAN_W03 KAMAN_W07 KAMAN_U06 KAMAN_U08 KAMAN_U09 KAMAN_U15 KAMAN_U16 KAMAN_U24 KAMAN_U25 KAMAN_K01 KAMAN_K06	60	180	6	6	3	T	E (w)		DN	P(2)	PD, S(MIC)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

		Life Insurance Models **(GK)**	2	2				KAMAN_W03 KAMAN_W09 KAMAN_W22 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (FAM)
		Total	6	6					180	480	16	16	9					6	

Optional courses / groups of courses Number of ECTS points 14

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Optional specialization course							60	150	5	5	3	T			DN	P(2)	S
		Optional specialization course							60	150	5	5	3	T			DN	P(2)	S
		Social course	2					KAMAN_W19 KAMAN_W23, KAMAN_U22 KAMAN_U27 KAMAN_K08, KAMAN_K10 KAMAN_K11	30	75	3		3	T		O			KO
		Foreign language		1				KAMAN_W13, KAMAN_K06	15	30	1		1	T		O			KO
		Total							165	405	14	10	10					4	

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

Altogether in semester

Total number of hours					Total number of ZZU hours	Total number of CNPS hours	Total number of ECTS points	Total number of ECTS points for DN classes[5]	Number of ECTS points for BU classes[1]
lec	cl	lab	pr	sem					
					345	885	30	26	19

Semester 2

Obligatory courses / groups of courses Number of ECTS points 11

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Optimization theory **(GK)**	2	2				KAMAN_W01 KAMAN _W02 KAMAN _W03 KAMAN _W06 KAMAN _W07 KAMAN _W08 KAMAN_W10 KAMAN_W15 KAMAN_U01 KAMAN_U11 KAMAN_U19 KAMAN_U24	60	180	6	6	3	T	E(w)		DN	P(2)	S (MSO)

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_U25 KAMAN_U29 KAMAN_K01 KAMAN_K02 KAMAN_K06 KAMAN_K07 KAMAN_K03 KAMAN_K04 KAMAN_K05											
		Agent-based modelling of complex systems **(GK)**	2		2			KAMAN_W08, KAMAN_W09 KAMAN_W11 KAMAN_U23 KAMAN_U17 KAMAN_U18 KAMAN_U24 KAMAN_U25 KAMAN_K02, KAMAN_K06	60	150	5	5	3	T	E(w)		DN	P(2)	S (DAT)
		Total	4	2	2				120	330	11	11	6					4	

Optional courses / groups of courses Number of ECTS points 19

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Optional specialization course							60	150	5	5	3	T			DN	P(2)	S

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

		Optional specialization course							60	150	5	5	3	T			DN	P(2)	S
		Optional specialization course							60	150	5	5	3	T			DN	P(2)	S
		/Humanities course	2					KAMAN_W19, KAMAN_W23, KAMAN_U22 KAMAN_U27 KAMAN_K08, KAMAN_K10, KAMAN_K11	15	50	2		2	T		O			KO
		Foreign language		3				KAMAN_W13, KAMAN_K06	45	60	2		2	T		O			KO
		Total							240	560	19	15	13					6	

Altogether in semester

Total number of hours					Total number of ZZU hours	Total number of CNPS hours	Total number of ECTS points	Total number of ECTS points for DN classes[5]	Number of ECTS points for BU classes[1]
lec	cl	lab	pr	sem					
					360	890	30	26	19

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

Semester 3

Obligatory courses / groups of courses Number of ECTS points 2

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Diploma Seminar					2	KAMAN_W03 KAMAN_W09 KAMAN_U15 KAMAN_U24 KAMAN_U25 KAMAN_K06	30	60	2	2	1	T	Z		DN	P(2)	S
		Total					2		30	60	2	2	1					2	

Optional courses / groups of courses Number of ECTS points 23

No.	Course/ group of courses code	Name of course/group of courses (denote group of courses with symbol **GK**)	Weekly number of hours					Learning effect symbol	Number of hours		Number of ECTS points			Form[2] of course/group of courses	Way[3] of crediting	Course/group of courses			
			lec	cl	lab	pr	sem		ZZU	CNPS	Total	DN[5] classes	BU[1] classes			University-wide[4]	Concerning scientific activities[5]	Practical[6]	Type[7]
		Diploma Thesis						KAMAN_W03 KAMAN_W04 KAMAN_W05 KAMAN_W09 KAMAN_W12	90	840	28	28	8					22	

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

								KAMAN_W14 KAMAN_W20 KAMAN_W21 KAMAN_U02 KAMAN_U03 KAMAN_U04 KAMAN_U05 KAMAN_U07 KAMAN_U10 KAMAN_U12 KAMAN_U13 KAMAN_U14 KAMAN_U15 KAMAN_U21 KAMAN_U24 KAMAN_U25 KAMAN_U26 KAMAN_U28 KAMAN_U30 KAMAN_K06											
		Kurs specjalnościowy wybieralny/Optional specialization course							60	150	5	5	3	T			DN	P(2)	S
		Total							150	840	28	28	11					22	

Altogether in semester

Total number of hours					Total number of ZZU hours	Total number of CNPS hours	Total number of ECTS points	Total number of ECTS points for DN classes[5]	Number of ECTS points for BU classes[1]
lec	cl	lab	pr	sem					
					120	900	30	30	11

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

2. Set of examinations in semestral arrangement

Course / group of courses code	Names of courses / groups of courses ending with examination	Semester
	1. Economathematics 2. Partial differential equations with applications in physics and industry 3. Life Insurance Models	1
	1. Optimization theory 2. Agent-based modelling of complex systems	2
	-	3

3. Numbers of allowable deficit of ECTS points after particular semesters

Semester	Allowable deficit of ECTS points after semester
1	10
2	10
3	0

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

Opinion of student government legislative body

....	....
Date	Name and surname, signature of student representative
....	....
Date	Dean’s signature

[1]BU – number of ECTS points assigned to hours of classes requiring direct participation of academic teachers and other persons conducting classes
[2]Traditional – enter T, remote – enter Z
[3]Exam – enter E, crediting – enter Z. For the group of courses – after the letter E or Z - enter in brackets the final course form (lec, cl, lab, pr, sem)
[4]University-wide course /group of courses – enter O
[5]DN - number of ECTS points assigned to the classes related to the University's academic activity in the discipline/disciplines to which the main field of study is assigned
[6]Practical course / group of courses – enter P. For the group of courses – in brackets enter the number of ECTS points assigned to practical courses
[7]KO – general education courses, PD – basic sciences courses, K – main field of study courses, S – specialization courses

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Zaawansowane zagadnienia z teorii gier dynamicznych
Name of subject in English: Advanced Topics in Dynamic Games
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Modelling, Simulation, Optimization
Profile: academic / practical*
Level and form of studies: 2nd level/ full-time/
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	3				

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has a basic knowledge of the calculus, algebra and the probability theory.
2. Student has a basic knowledge of game theory.

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SUBJECT OBJECTIVES

C1. Basic knowledge of Markov decision processes.
C2. Basic knowledge of algorithms allowing to find value functions and optimal policies.
C3. Basic knowledge of simple markovian decision models.
C4. Basic knowledge of stochastic game models.
C5. Basic knowledge of theory and applications of mean field games.
C6. Ability to apply the acquired knowledge to create and analyze dynamic optimization models in various fields of science and technology.

SUBJECT EDUCATIONAL EFFECTS

The scope of the student's knowledge:

PEU_W01 Students knows basic concepts of dynamic programming.

PEU_W02. Student knows basics of theory of stochastic games. PEU_W03. Student knows basics of theory of mean field games. The scope of the student's skills: PEU_U01 Student is able to find an optimal policy and value function in a simple markovian decision process. PEU_U02. Student is able to check whether a vector of strategies forms a Nash equilibrium in a given simple stochastic game. PEU_U03. Student is able to construct an appropriate dynamic model of a given optimization problem. The scope of the student's social skills: PEU_K01. Student is able to utilise literature pointed out by the lecturer. PEU_K02. Student is able to use computer programs in order to solve some issues. PEU_K03. Student understands the necessity of further self-learning.

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec1	Introduction to markovian decision processes, the concept of a policy, different optimality criteria, examples of simple models.	2
Lec2	Dynamic programming method. Solving models with finite time horizon. Backward induction.	2
Lec3	Models with infinite time horizon. The Banach fixed point theorem and its application to a solution of the Bellman equation.	2
Lec4	Algorithms applied to infinite time horizon models: value iteration, policy improvement, LP.	4
Lec5	Markov decision processes with risk sensitive payoff criteria. Other payoff criteria.	2
Lec6	Specific models.	2
Lec7	Two-person zero-sum discounted stochastic games. The theorem of Shapley.	4
Lec8	Nonzero-sum discounted stochastic games.	2
Lec9	Stochastic games with other payoff criteria.	2
Lec10	Applications of stochastic games in economics and engineering.	2
Lec11	Mean field games. The existence of solutions. Relation with games with a finite number of players. Examples of applications in economics and engineering.	4
Lec12	Summary and exam.	2
	Total hours	**30**

Classes		**Number of hours**
Cl 1	Markov chains.	2
Cl 2	Solving different markovian decision models.	14
Cl 3	Solving different stochastic game models.	14
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method N2. Exercise and accounting problems - the traditional method. N3. Consultation. N4. Student's own work - preparing to exercise and test.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01,PEU_W02, PEU_W03, PEU_U01,PEU_U02, PEU_U03,PEU_K01, PEU_K02	oral presentations, quizzes
F2	PEU_W01,PEU_W02, PEU_U01,PEU_U02, PEU_U03,PEU_K01, PEU_K02	exam
P=0,5*F1+0,5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] M. Puterman, Markov decision processes, Wiley 1994.
[2] N. Stockey, R. Lucas, E. Prescott, Recursive methods in economic dynamics, Harvard University Press, 1989.
[3] A. Haurie, J.B. Krawczyk, G. Zaccour. Games and Dynamic Games. World Scientific, 2012.

SECONDARY LITERATURE:

[4] H, Tijms, A first course in stochastic models, Wiley 2003.
[5] B. Jovanovic and R. W. Rosenthal. Anonymous sequential games. Journal of Mathematical Economics, 17:77–87, 1988.
[6] O. Gueant, J-M. Lasry, P-L. Lions, Mean field games and applications. W R. Carmona et al., editor, Paris Princeton Lectures in Mathematical Finance IV, Lecture Notes in Mathematics v.2003. Springer Verlag, 2010.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. inż. Anna Jaskiewicz (Anna.Jaskiewicz@pwr.edu.pl)
Dr Piotr Więcek (Piotr.Wiecek@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name of subject in Polish: **Zaawansowane zastosowania pakietów statystycznych**
Name of subject in English: **Advanced Applications of Statistical Packages**
Main field of study: **Applied Mathematics**
Specialization: **Data Engineering**
Profile: **Academic**
Level and form of studies: **2nd level, full-time**
Kind of subject: **Optional**
Subject code:
Group of courses: **YES**

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	~~Examination~~ / crediting with grade*	~~Examination / crediting with grade*~~	~~Examination~~ / crediting with grade*	~~Examination / crediting with grade*~~	~~Examination / crediting with grade*~~
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1.5		1.5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Probability theory and mathematical statistics mastered at the level corresponding to the first degree of mathematical studies.
2. Knowledge of theoretical foundations and the ability to fit a linear regression model.
3. Good knowledge of any procedural programming language, basics of S language are recommended.
4. Familiarity with any math or statistics package that has a programming language built-in in addition to a graphical user interface.

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SUBJECT OBJECTIVES

C1 A review of advanced applications of statistical packages.
C2 Improving the skills of using the R statistical package.

SUBJECT EDUCATIONAL EFFECTS
relating to knowledge: PEU_W01 The student knows the difference between the predictive and confirmatory approach to modeling. relating to skills: PEU_U01 The student is able to use the R package utilizing the tidyverse and tidymodels package ecosystem. PEU_U02 The student is able to analyze data using advanced statistical models. relating to social competences: PEU_K01 The student is prepared to acquire new competences and independently analyze data in search of answers to the questions he is interested in.

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec1	Introduction to the lecture; Determining topics for the 1st and 2nd thematic blocks for lectures 7–14; Discussion about differences between predictive and confirmatory approaches to modeling.	2
Lec2	Introduction to generalized linear models; Exponential family of distributions and its properties.	2
Lec3	Estimation and reasoning about parameters in generalized linear models.	2
Lec4	Comparing generalized linear models; Variable selection methods; Verification of assumptions of a generalized linear model.	2
Lec5	Special cases of the generalized linear model for discrete data – logistic, Poisson and negative binomial regression.	2
Lec6	Regularization methods: Lasso, ridge and Elastic-Net; Zero-inflated Poisson and negative binomial regression.	2
Lec7-Lec10	1st thematic block – one of the topics illustrating advanced applications of statistical packages, e.g.: analysis of interval-censored data, Bayesian models, bootstrap methods, generalized linear mixed models, statistical tools of meta-analysis, spatial statistics, statistics of finite populations.	8
Lec11-Lec14	2nd thematic block – one of the topics illustrating advanced applications of statistical packages from the same pool, but different from selected in the first block.	8
Lec15	Lecture summary.	2
	Total hours	**30**

Laboratory		**Number of hours**
Lab1	Reading and processing data in tidyverse.	2
Lab2	Data visualization in ggplot2.	2
Lab3	Fitting models using tidymodels.	2
Lab4-Lab7	Exercises illustrating fitting and statistical inference for generalized linear models in confirmatory and predictive approaches.	8

Lab8-Lab11	Exercises illustrating the topic presented in the first thematic block (lectures 7–10).	8
Lab12-La15	Exercises illustrating the topic presented in the second thematic block (lectures 11–14).	8
	Total hours	**30**

TEACHING TOOLS USED
N1. Computer presentation and traditional methods. N2. Computer laboratory. N3. Student’s self work.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_U01 PEU_U02 PEU_K01	Three laboratory reports performed in small student groups.
F2	PEU_W01 PEU_U02	A test during lecture.
P = 5/7 * F1 + 2/7 * F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] H. Wickham, M. Çetinkaya-Rundel, G. Grolemund, *R for Data Science*, O’Reilly 2023, wydanie 2.
[2] M. Kuhn, J. Silge, *Tidy Modeling with R*, O’Reilly 2022, wydanie 1.
[3] E. Jones, S. Harden, M. J. Crawley, *The R Book*, Wiley 2022, wydanie 3.
[4] A. Agresti, *Foundations of Linear and Generalized Linear Models*, Willey 2015, wydanie 1.

SECONDARY LITERATURE:

[1] E. Gentle, W. K. Härdle, Y. Mori, *Handbook of Computational Statistics*, Springer 2012, wydanie 2.
[2] K. Bogaerts, A. Komarek, E. Lesaffre, *Survival Analysis with Interval-Censored Data*, Chapman & Hall 2018, wydanie 1.
[3] R. McElreath, *Statistical Rethinking: A Bayesian Course with Examples in R and Stan*, Chapman and Hall 2020, wydanie 2.
[4] B. Efron, R. J. Tibshirani, *An Introduction to the Bootstrap*, Chapman and Hall 1993, wydanie 1.
[5] W. W. Stroup, *Generalized linear mixed models: modern concepts, methods and applications*, Chapman and Hall 2012, wydanie 1.
[6] G. Schwarzer, *Meta-Analysis with R*, Springer 2015, wydanie 1.

[7] R. S. Bivand, E. Pebesma, V. Gómez-Rubio, *Applied Spatial Data Analysis with R*, Springer 2008, wydanie 1.
[8] Y. Tillé, *Sampling and Estimation from Finite Populations*, Wiley 2020, wydanie 1.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Andrzej Giniewicz (Andrzej.Giniewicz@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name in Polish: Modelowanie Agentowe Układów
Name in English Agent-based modelling of Complex Systems
Main field of study (if applicable): Applied Mathematics
Level and form of studies: ~~1st~~/ 2nd* level, full-time / ~~part-time*~~
Kind of subject: obligatory ~~/ optional / university-wide*~~
Subject code
Group of courses ~~TAK~~ / NO*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical (P) classes	2		2		
including number of ECTS points for direct teacher-student contact (BK) classes	1,5		1,5		

*delete as applicable

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has the standard knowledge of computational methods in mathematics.
2. Student has basic programming skills.

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SUBJECT OBJECTIVES

C1 Analysis of complex systems by making use of agent-based modelling methods.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows advanced computational methods and understand their limitations

PEU_W02 knows basic stochastic modelling methods in financial and actuarial mathematics or in science

relating to skills:
PEU_U01 can construct and perform computer simulations and simple experiments, can interpret obtained results and draw conclusions

relating to social competences:
PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PEU_K02 can accurately formulate questions for deeper understanding of a given topic

PROGRAMME CONTENT

Form of classes - lecture		Number of hours
Lec 1	Introduction to agent-based modelling	2
Lec 2	Introduction to agent-based modelling	2
Lec 3	Creating simple agent-based models	2
Lec 4	Creating simple agent-based models	2
Lec 5	Exploring and extending agent-based models	2
Lec 6	Exploring and extending agent-based models	2
Lec 7	Exploring and extending agent-based models	2
Lec 8	Exploring and extending agent-based models	2
Lec 9	Components of agent-based models	2
Lec 10	Components of agent-based models	2
Lec 11	Analyzing agent-based simulations	2
Lec 12	Analyzing agent-based simulations	2
Lec 13	Verification and validation of agent-based models	2
Lec 14	Computational roots of agent-based modelling	2
Lec 15	Models of natural and social complex systems - examples	2
	Total hours	**30**

Form of classes - laboratory		Number of hours
La 1	Practical introduction to Python modules for agent-based modelling	2
La 2	Practical introduction to Netlogo	2
La 3	Simple agent-based models (life, ant, heroes and cowards models)	4
La 4	Analysis of existing models (fire, segregation and El Farol models)	8
La 5	SI epidemics model – implementation and analysis	4
La 6	SIR epidemics model – implementation and analysis	2
La 7	Voter and q-voter models – implementation and analysis	8
	Total hours	**30**

TEACHING TOOLS USED

N1. Lecture – traditional method and presentations
N2. Problem and computing laboratory – using computer based methods

N3. Consultations N4. Student's self work – preparation for the laboratory

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01 PEU_W02	exam
F2	PEU_U01 PEU_K01 PEU_K02	Oral presentations
C P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] Uri Wilensky, William Rand, "An Introduction to Agent-Based Modeling"

[2] Steven F. Railsback, Volker Grimm, "Agent-Based and Individual-Based Modeling: A Practical Introduction"

SECONDARY LITERATURE:

[1] Robert Siegfried, „Modeling and Simulation of Complex Systems: A Framework for Efficient Agent-Based Modeling and Simulation"

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. Inż. Janusz Szwabiński, prof. uczelni (janusz.szwabinski@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name of subject in Polish: ANALIZA NIEUPORZĄDKOWANYCH ZBIORÓW DANYCH
Name of subject in English: ANALYSIS OF UNSTRUCTURED DATA
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): COMPUTATIONAL MATHEMATICS
Profile: academic / practical*
Level and form of studies: ~~1st~~/ 2nd* level, full-time / ~~part-time*~~
Kind of subject: ~~obligatory~~ ~~/~~ optional ~~/ university-wide*~~
Subject code:
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30			30	
Number of hours of total student workload (CNPS)	90			60	
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3			2	
including number of ECTS points for practical classes (P)	2			2	
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5			1,5	

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has basic programming skills.

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SUBJECT OBJECTIVES

C1 Searching, extracting, storing ond computer-aided analysis of unstructered data (texts, blogs, web sites, social media posts etc.)

SUBJECT EDUCATIONAL EFFECTS

Relating to knowledge:
PEU_W12 knows how to use Python and its scientific modules for data analysis
Relating to skills:
PEU_U12 can perform an analysis of unstructured data by making use of Python and its modules
Relating to social competences:
PEU_K06 can, without assistance, search for necessary information in the literature, also in foreign languages

PEU_K02 can accurately formulate questions for deeper understanding of a given topic

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Data analysis in Python – PANDAS primer	8
Lec 2	Retrieving and storing data	6
Lec 3	Data visualisation	2
Lec 4	Data wrangling	2
Lec 5	Natural language processing with NLTK	4
Lec 6	Sentiment analysis	2
Lec 7	Document classification	4
Lec 8	Handling big data	2
	Total hours	**30**

Project		**Number of hours**
Pr1	Practical Preparation and presentations of projects illustrating methods given in the lectures.	30
	Total hours	30

TEACHING TOOLS USED
1. Lecture – traditional method and presentations 2. Student partial project presentation and final presentation 3. Consultations 4. Student's self work – work related to the project development

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W12 PEU_U12	mid-term exams
F2	PEU_U12 PEU_K06 PEU_K02	Oral presentations
C P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] S. Bird, E. Klein i E. Loper, „Natural Language Processing with Python”
[2] I. H. Witten & E. Frank, „Data Mining. Practical Machine Learning Tools and Techniques”
[3] W. McKinney, „Python for Data Analysis”

SECONDARY LITERATURE:

[1] P. Giudici, „Applied Data Mining”
[2] T. Segaran, „Programming Collective Intelligence”
[3] I. Idris, „Python Data Analysis”

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
JANUSZ SZWABIŃSKI

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish Analiza Funcjonalna i jej zastosowania
Name of subject in English Applied Functional_analysis
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): Mathematics for Industry and Commerce
Level and form of studies: ~~1st~~/ 2nd* level, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic concepts of mathematical analysis
2. Student knows and can apply basic concepts of linear algebra

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SUBJECT OBJECTIVES

C1 Study of the classical concepts of topology, elements of optimization and functional analysis and its application to solve simple inverse problems

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:

PEU_W01 knows the most important theorems and hypothesis of functional analysis, topology

PEU_W02 knows basic methods of optimisation

relating to skills:

PEU_U01 knows and can apply methods of functional analysis

relating to social competences:

PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec1	Introduction to functional analysis – real world problems modeled by operator equations	4
Lec 2	Elements of topology and linear spaces	2
Lec 3	Linear normed spaces	2
Lec 4	Hilbert spaces	2
Lec 5	Linear operators	4
Lec 6	Elements of spectra theory	4
Lec 7	Fundaments of optimisation	4
Lec 8	Role of functional analysis in solving inverse problems	4
Lec 9	Elements of functional analysis in numerical methods	4
	Total hours	**30**

Laboratory		**Number of hours**
Lab1	Solving of problems illustrating theory given in the lectures using mathematical packages for numerical computing	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method N2. Computer laboratory N3. Consultations N4. Student's self work – preparation for the laboratory

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P –	Learning outcomes code	Way of evaluating learning outcomes achievement

concluding (at semester end)		
F1	PEU_W01 PEU_W02 PEU_K01	examination
F2	PEU_U01 PEU-K01	oral presentations, tests, projects, raports
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] E. Zeidler, Applied Functional Analysis, Springer-Verlag 1995
[2] Ch.W. Groetsch, Inverse Problems in the Mathematical Science, Vieweg-Verlag 1993

PRIMARY LITERATURE:

[1] L. Debnath, P. Mikusiński, Introduction to Hilbert Spaces with Applictions, Academic Press 2005

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Prof. dr hab. Wojciech Okrasiński (Wojciech.Okrasinski@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name in Polish: Finanse Obliczeniowe
Name in English: Computational Finance
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): FINANCIAL AND ACTUARIAL MATHEMATICS, COMPUTATIONAL MATHEMATICS
Profile: academic / ~~practical~~*
Level and form of studies: ~~1st/~~ 2nd level, ~~uniform magister studies~~*, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code:
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	~~Examination~~ / crediting with grade*	Examination / crediting with grade*	~~Examination /~~ crediting with grade*	Examination / crediting with grade*	Examination / crediting with grade*
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic notions of financial mathematics.
2. Student knows basics of computer programming.

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SUBJECT OBJECTIVES

C1 Study of concepts and acquisition of knowledge concerning algorithms and methods in computational finance

C2 Acquisition of abilities in implementing selected models and methods

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge the student:

PEU_W01 knows basic models and algorithms used in finance

PEU_W02 has in-depth knowledge regarding numerical implementation of selected derivatives pricing techniques

relating to skills the student:

PEU_U01 can implement and apply in practice computational techniques used in finance

relating to social competences the student: PEU_K01 can, without assistance, search for necessary information in the scientific literature

PROGRAMME CONTENT

Lecture		Number of hours
Lec1	Derivatives: forwards, futures, swaps and options. Portfolio construction and pricing.	2
Lec2-3	Partial differential equations technique. Pricing in the Black-Scholes model.	4
Lec4-5	Sensitivity analysis. Delta-neutral and delta-gamma-neutral strategies.	4
Lec6	Volatility modeling	2
Lec7-8	Binomial pricing: CRR, JR and „exact” trees. Hedging strategies on trees. Trinomial trees.	4
Lec9-10	Binomial and trinomial pricing of path dependent derivatives.	4
Lec11-12	Finite difference schemes: explicit, implicit, Crank-Nicolson.	4
Lec13-14	Monte Carlo method in finance. Euler and Milstein schemes, variance reduction.	4
Lec15	MC pricing of American options.	2
	Total hours	30

Laboratory		Number of hours
Lab1-15	Implementation (Matlab, R, Excel/VB, C++, Java and/or Python) of algorithms and methods discussed during lectures	30
	Total hours	30

TEACHING TOOLS USED

N1. Lecture – traditional method
N2. Laboratory – traditional method

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02	Test
F2	PEU_U01	Exercises
F3	PEU_K01	Project
P=0.34F1+0.33F2+0.33F3		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] P. Wilmott (2000) Paul Wilmott on Quantitative Finance, Wiley [2] J. Hull (2008) Options, Futures and Other Derivatives (7th Edition), Prentice Hall [3] J. London (2005) Modeling Derivatives in C, Wiley [4] A. Weron, R. Weron (1998, …, 2009) Inżynieria finansowa, WNT. **SECONDARY LITERATURE:** [5] Z. Bodie, A. Kane, A.J. Marcus (2007) Essentials of Investments (6th ed.), McGraw-Hill [6] M. Capiński, T. Zastawniak (2003) Mathematics for Finance: An Introduction to Financial Engineering, Springer [7] P.Cizek, W.Härdle, R.Weron, eds. (2011) Statistical Tools for Finance and Insurance, Springer [8] J. Franke, W. Härdle, C. Hafner (2005) Introduction to Statistics of Financial Markets, Springer [9] P. Glasserman (2004) Monte Carlo Methods in Financial Engineering, Springer
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
dr inż. Joanna Janczura (joanna.janczura@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name of subject in Polish: SYMULACJE KOMPUTEROWE PROCESÓW STOCHASTYCZNYCH
Name of subject in English: **Computer simulations of stochastic processes**
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): COMPUTATIONAL MATHEMATICS, MODELLING, SIMULATION, OPTIMIZATION
Profile: academic / practical*
Level and form of studies: ~~1st/~~ 2nd* level, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic concepts of the theory of stochastic processes.

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SUBJECT OBJECTIVES

C1 Mastering knowledge of computer simulations of stochastic processes with long memory property and heavy tails.

SUBJECT EDUCATIONAL EFFECTS
relating to knowledge: PEU_W01 has in-depth knowledge of computer simulations of stochastic processes with long memory property and heavy tails. PEU_W02 knows the basics of stochastic modeling in financial and actuarial mathematics or the natural sciences, especially physics, chemistry or biology relating to skills: PEU_U01 can construct algorithms with good numerical properties, used to solve common and unusual mathematical problems relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT

Lecture		Number of hours
Lec 1	Generation of stable distributions and vectors	6
Lec 2	Simulation of stable processes by integral and series representations	6
Lec 3	Self-similar and stationary processes	6
Lec 4	Generating processes with long memory	6
Lec 5	Stable models with long memory in physics and economics	6
	Total hours	30

Laboratory		Number of hours
Lab 1	Solving problems illustrating methods given in the lecture.	30
	Total hours	**30**

TEACHING TOOLS USED

N1. Lecture-computer presentation and traditional method.
N2. Computer Laboratory with Matlab
N3. Consultations.
N4. Student's self work – preparation for the laboratory.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01 PEU_W02 PEU_K01	test
F2	PEU_U01	written reports

	PEU_K01	
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] P. Doukhan, G. Oppenheim, M.S. Taqqu, Theory and Applications of Long-range Dependence, Birkhauser, Boston, 2004.
[2] A. Janicki, A Weron, Simulation and Chaotic Behavior of Stable Stochastic Processes, Marcel Dekker, New York, 1994.
[3] G. Samorodnitsky, M.S. Taqqu, Stable Non-Gaussian Random Processes, Chapman & Hall, New York, 1994.

SECONDARY LITERATURE:

[1] J. Beran, Statistics for Long-memory Processes, Chapman & Hall, New York, 1994.
[2] P. Cizek, W. Haerdle, R. Weron (red.), Statistical tools for finance and insurance, Springer, Berlin, 2011.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr Krzysztof Burnecki (Krzysztof.Burnecki@pwr.edu.pl) **Dr hab. Marcin Magdziarz** (Marcin.Magdziarz@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Pozyskiwanie wiedzy
Name of subject in English: Data mining
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Data engineering
Profile: academic / practical*
Level and form of studies: 2nd level / full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Introduction to probability theory
2. Introduction to mathematical statistics
3. Introduction to programming

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SUBJECT OBJECTIVES

C1 Knowledge of basic data mining tasks
C2 Knowledge of classical and modern approaches used for classification, dimension reduction and cluster analysis
C3 Knowledge of procedures used to evaluate the performance of classification or cluster analysis algorithms
C4 Use of acquired knowledge in solving practical problems from different areas of science, technology and economics

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 has knowledge related to different data mining tasks

PEU_W02 knows basic methods/algorithms used for classification, dimension reduction, cluster analysis, association rules discovery, and knows properties of these methods
PEU_W03 knows procedures used in evaluating quality of classification or clustering results
relating to skills:
PEU_U01 can choose appropriate methods to solve a given data exploration task
PEU_U02 knows how to use both supervised and unsupervised learning algorithms
PEU_U03 knows how to evaluate the performance of data mining procedures
relating to social competences:
PEU_K01 can, without assistance, search for necessary information in the literature and acquire knowledge independently
PEU_K02 understands the need for systematic and independent work on mastery of course material

PROGRAMME CONTENT

Lecture		Number of hours
Lec 1	Introduction to the basic concepts of data mining. The types of data exploration tasks.	2
Lec 2	Data preparation for data mining analysis: handling missing values, identification of outliers and necessary transformations.	4
Lec 3	Dimension reduction methods: Principal Components Analysis (PCA), Multidimensional Scaling (MDS).	4
Lec 4	Methods used for data classification: k-nearest neighbors (K-NN), classification tree, naive Bayes classifier, discriminant analysis, logistic regression.	6
Lec 5	Cluster analysis. Partitioning and hierarchical methods (k-means, PAM, AGNES, DIANA).	4
Lec 6	Evaluation of the quality of classification and clustering results.	2
Lec 7	Support Vector Machines (SVM).	2
Lec 8	Ensemble methods in classification: bagging, boosting, random forest.	2
Lec 9	Introduction to the association rules mining.	2
Lec 10	Final test.	2
	Total hours	30

Laboratory		Number of hours
Lab 1	Introduction to R statistical environment.	2
Lab 2	Data structures and elements of programming in R.	2
Lab 3	Exploratory analysis of multivariate data.	2
Lab 4	Data preparation (handling missing values, identification of outliers and necessary data transformations).	2
Lab 5	Dimension reduction methods (PCA, MDS).	3
Lab 6	K-nearest neighbors (K-nn) algorithm and classification trees.	2

Lab 7	Discriminant analysis and logistic regression.	3
Lab 8	Cluster analysis – partitioning algorithms (k-means, PAM).	2
Lab 9	Cluster analysis – hierarchical algorithms (AGNES, DIANA, MONA).	2
Lab 10	Evaluation of classification and cluster analysis results.	3
Lab 11	Support Vector Machines (SVM).	2
Lab 12	Classifier ensembles: bagging, boosting, random forest	3
Lab 13	Association rules discovery.	2
	Total hours	30

TEACHING TOOLS USED

N1. Lecture – traditional method
N2. Computer lab classes
N3. Consultations
N4. Student's self work – preparation for the classes

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_U01, PEU_U02, PEU_U03, PEU_K01, PEU_K02,	Oral presentations, written reports, individual projects.
F2	PEU_W01, PEU_W02, PEU_W03, PEU_K01, PEU_K02,	Test
P = 60%F1 + 40%F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] P.-N. Tan, M. Steinbach, V. Kumar, Introduction to Data Mining, Addison-Wesley, 2006.

[2] G.James, D.Witten, T.Hastie, R.Tibshirani, An Introduction to Statistical Learning with Applications in R, Springer, 2017.

[3] T.Hastie, R.Tibshirani, J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer, 2017.

[4] D.T. Larose, Discovering Knowledge in Data: An Introduction to Data Mining, Wiley, 2005.

[5] D.T. Larose, Data Mining Methods and Models, Wiley, 2006.

SECONDARY LITERATURE:

[1] Ch. M. Bishop, Pattern Recognition and Machine Learning (Information Science and Statistics). Springer, 2006.

[2] W.N. Venables, B.D. Ripley, Modern Applied Statistics With S, Springer, 2001.

[3] R.A. Johnson, D.W. Wichern, Applied multivariate statistical analysis, Pearson Prentice Hall, 2002.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

dr inż. Adam Zagdański (Adam.Zagdanski@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name in Polish: Dyfuzja na sieciach złożonych
Name in English: Diffusion processes on complex networks
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Computional mathematics
Profile: academic / practical*
Level and form of studies: 2nd* level, full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical (P) classes	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as applicable

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has basic programming skills.

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SUBJECT OBJECTIVES

C1 Mastering knowledge of computer simulation of diffusion processes on complex networks.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:

PEU_W04 has in-depth knowledge in a subfield of theoretical or applied mathematics

PEU_W09 knows basic stochastic modelling methods in financial and actuarial mathematics or in science

relating to skills:

PEU_U18 can use stochastic processes as a tool for modelling complex phenomena and analysis of their evolution

relating to social competences: PEU_K06 can, without assistance, search for necessary information in the literature, also in foreign languages PEU_K02 can accurately formulate questions for deeper understanding of a given topic

PROGRAMME CONTENT		
Form of classes - lecture		**Number of hours**
Lec 1	Introduction to complex networks	10
Lec 2	Diffusion and random walks	2
Lec 3	Epidemic spreading in population networks	6
Lec 4	Rumor and information spreading	2
Lec 5	Opinion formation processes	4
Lec 6	Diffusion of innovation	6
	Total hours	**30**

Form of classes - classes		**Number of hours**
Cl 1	Solving problems illustrating the content presented in the lectures	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method and presentations N2. Problem and computing laboratory – using computer based methods N3. Consultations N4. Student's self work – preparation for the laboratory

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W04 PEU_W09	Mid-term exams

F2	PEU_U18 PEU_K02 PEU_K06	Oral presentations
P= 0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] Alain Barrat, Marc Barthelemy, Alessandro Vespignani, "Dynamical Processes on Complex Networks" [2] Romualdo Pastor-Satorras, Claudio Castellano, Piet Van Mieghem, Alessandro Vespignani, "Epidemic processes in complex networks", Revies of Modern Physics 87 (2015) 925-979 **SECONDARY LITERATURE:** [1] David Easley, Jon Kleinberg, „Networks, Crowds, and Markets: Reasoning about a Highly Connected World"
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Seminarium Dyplomowe
Name of subject in English: Diploma Seminar
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Financial and Actuarial Mathematics;
Mathematics for Industry and Commerce;
Data Engineering;
Modelling, Simulation and Optimization
Profile: academic / practical*
Level and form of studies: 2nd level / full-time /
Kind of subject: obligatory ~~/ optional / university-wide*~~
Subject code
Group of courses ~~YES~~ / NO*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)					30
Number of hours of total student workload (CNPS)					60
Form of crediting					~~Examination~~ / crediting with grade*
For group of courses mark (X) final course					
Number of ECTS points					5
including number of ECTS points for practical (P) classes					4
including number of ECTS points for direct teacher-student contact (BK) classes					3

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has an advanced knowledge and skills in the field of calculus, functional analysis and the theory of differentia equations.
2. She has got a thorough knowledge and skills in the field of probability, mathematical statistics and the theory of stochastic processes.

SUBJECT OBJECTIVES

C1 Learning about achievements and new methods used in various applications of mathematics.

*delete as inapplicable

SUBJECT EDUCATIONAL EFFECTS
Relating to knowledge: PEU_W01 knows fundamental models and methods used in various applications of mathematics PEU_W02 knows the fundamentals of stochastic modeling Relating to skills: PEU_U01 can build basic mathematical models, used in various disciplines Relating to social competences: PEU_K01 can use the scientific literature (also in foreign languages), including finding source information and browse through articles

Form of classes - seminar		Number of hours
Se1	Master thesis results presentations.	30
	Total hours	**30**

TEACHING TOOLS USED
1. Problem Seminar, presentation, problem lecture, informative lecture 2. Student's self-work – preparation for the seminar

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01 PEU_W02 PEU_U01 PEU_K01	Evaluation of the presentation, informative or problem lecture prepared by the student
P=F1		

PRIMARY AND SECONDARY LITERATURE
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Prof. dr hab. Marcin Magdziarz (marcin.magdziarz@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name in Polish: Praca dyplomowa
Name in English: Diploma thesis
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Financial and Actuarial Mathematics;
Mathematics for Industry and Commerce;
Data Engineering;
Modelling, Simulation and Optimization
Level and form of studies: ~~1st/~~ 2nd* level, full-time / ~~part-time~~*
Kind of subject: obligatory ~~/ optional~~ / ~~university-wide~~*
Subject code
Group of courses ~~YES~~ / NO*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)					30
Number of hours of total student workload (CNPS)					690
Form of crediting					~~Examination~~ / crediting with grade*
For group of courses mark (X) final course					
Number of ECTS points					23
including number of ECTS points for practical (P) classes					10
including number of ECTS points for direct teacher-student contact (BK) classes					5

*delete as applicable

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES
1. Student has the advanced knowledge and skills in the field of mathematical analysis, functional analysis and the theory of differential equations
2. He has deeper knowledge and skills in the field of probability theory, mathematical statistics and the theory of stochastic processes.

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SUBJECT OBJECTIVES
C1 Getting to know new developments and methods used in various applications of mathematics.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the basic models and methods used in various applications of mathematics
PEU_W02 knows the basics of stochastic modeling

relating to skills:
PEU_U01 able to construct basic mathematical models used in various fields

relating to social competences:
PEU_K01 can benefit from the scientific literature (including in foreign languages), including reaching the source materials and make them review

TEACHING TOOLS USED

N1. Student's own work - searching for information, writing thesis analysis of real data
N2. Consultations

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01 PEU_W02 PEU_U01 PEU_K01	evaluation of the student's self work, the assessment of the thesis
P=F1		

PRIMARY AND SECONDARY LITERATURE

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Prof. dr hab. Aleksander Weron (Aleksander.Weron@pwr.edu.pl)
Dr hab. Jan Goncerzewicz (Jan.Goncerzewicz@pwr.edu.pl)
Prof. dr hab. Krzysztof Szajowski (Krzysztof.Szajowski@pwr.edu.pl)
Dr hab. Agnieszka Jurlewicz, prof. nadzw. PWr. (Agnieszka.Jurlewicz@pwr.edu.pl)
Dr hab. Marcin Magdziarz, prof. nadzw. PWr. (Marcin.Magdziarz@pwr.edu.pl)
Dr hab. Agnieszka Wyłomańska, prof. nadzw. PWr. (Agnieszka.Wylomanska@pwr.edu.pl)
Dr Monika Muszkieta (Monika.Muszkieta@pwr.edu.pl)
Dr hab. Krzysztof Burnecki, prof. nadzw. PWr. (Krzysztof.Burnecki@pwr.edu.pl)
Dr Joanna Janczura (Joanna.Janczura@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD
Name in Polish: Matematyka finansowa
Name in English: Economathematics
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Financial and Actuarial Mathematics
Level and form of studies: ~~1st~~/ 2nd* level, full-time ~~/ part-time~~*
Kind of subject: obligatory ~~/ optional / university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	Examination / ~~crediting with grade~~*	Examination / crediting with grade*	Examination / crediting with grade*	Examination / crediting with grade*	Examination / crediting with grade*
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5	1,5			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has an elementary knowledge of financial markets and discrete models of financial mathematics

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SUBJECT OBJECTIVES

C1 Learning and mastery of key concepts and methods in the field of financial mathematics.

SUBJECT EDUCATIONAL EFFECTS
relating to knowledge:
PEU_W01 knows the most important theorems and hypotheses of financial mathematics
PEU_W02 knows the basics of stochastic modeling in financial mathematics
relating to skills:
PEU_U01 can construct mathematical models used in financial mathematics
relating to social competences:
PEU_K01 can by hisself search for information in the literature, even in foreign languages

PROGRAMME CONTENT		
Form of classes - lecture		Number of hours
Lec 1	Black-Scholes model	4
Lec 2	Stochastic calculus and its application to the valuation of assets and liabilities and design hedging strategies	4
Lec 3	Feynman-Kac formula and Blacka-Scholes formula	2
Lec 4	Bachelier model	2
Lec 5	Risk-Neutral and Real World scenarios, deflator and its applications	2
Lec 6	Modeling of term structure	2
Lec 7	Vasicek and Cox-Ingerson-Ross models, HJM model, LIBOR model	4
Lec 8	Calibration of interest rate instruments	2
Lec 9	Valuation of debt instruments and interest rate derivatives (bonds, cap/ floor, caplet/floorlet and swaptions)	2
Lec10	Subdiffusive Black-Scholes and Bachelier models	2
Lec11	Fractional Brownian motion in finance	2
Lec12	Gerber-Shiu model, Esscher transform	2
	Total hours	**30**

Form of classes - Class		Number of hours
Cl 1	Illustration of all models.. Analytical and computer methods. Examples of pricing derivatives.	**30**
	Total hours	**30**

TEACHING TOOLS USED
1. Lecture – traditional method
2. Problem and counting exercises.
3. Consultations.
4. Student's self work - preparation for exercises.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_K01	oral responses, tests, small tests
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] A. Weron, R. Weron (1998) Inżynieria finansowa, WNT **SECONDARY LITERATURE:** [1] A. Jakubowski, A. Palczewski, M. Rutkowski, Ł. Stettner (2003) Matematyka finansowa, WNT. [2] M. Musiela, M. Rutkowski (1997) Martingale methods in financial modelling, Springer.
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr hab. Marcin Magdziarz (Marcin.Magdziarz@pwr.edu.pl)

FACULTY OF FUNDAMENTAL PROBLEMS OF TECHNOLOGY
SUBJECT CARD
Name of subject in Polish: TEORIA ESTYMACJI
Name of subject in English: Estimation theory
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): COMPUTATIONAL MATHEMATICS
Profile: academic / practical*
Level and form of studies: ~~1st/~~ 2nd* level, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows how to use statistical packages
2. Student has a basic knowledge of mathematical statistics.
3. Student has a basic knowledge of mathematical analysis and functional analysis
4. Student has basic programming skills.

\

SUBJECT OBJECTIVES

C1 Learning of statistical criteria for assessing the quality of statistical estimation
C2 Learning basic parametric estimation methods and their properties.
C3 Learning basic non-parametric estimation methods and their properties.
C4 Ability to program advanced statistical methods.
C5 Ability to carry out simulation studies.
C6 Ability to evaluate properties of statistical methods based on simulation studies.
C7 Mastering of English vocabulary in the field of estimation methods .
C8 Report writing skills in English.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the basic parametric estimation methods.
PEU_W02 knows the basic non-parametric estimation methods.
PEU_W03 knows the basic criteria for assessing the quality of the estimation.
PEU_W04 knows the theoretical basis of statistical simulation.
PEU_W05 knows English in the extent necessary for the creation of simulation reports.
PEU_W06 knows Programming Languages enable to carry out the simulation study.

relating to skills:
PEU_U01 able to apply advanced statistical methods to analyze real data.
PEU_U02 can use programming languages to program the high-order complex statistical methods and simulation tests and to carry out simulation studies.
PEU_U03 able to assess the properties of statistical methods based on simulation studies.
PEU_U04 can develop a report in English summarizing the results of simulation studies.

relating to social competences:
PEU_K01 can benefit from the scientific literature in English, including reaching the source materials and review them.
PEU_K02 understands the need for systematic work to improve knowledge

PROGRAMME CONTENT

Lecture		Number of hours
Lec 1	Basic concepts of estimation theory: bias, variance, mean square error matrix of Fisher information, efficiency, asymptotic normality	2
Lec 2	Theoretical basis of simulation methods and replication	2
Lec 3	Bias and variance estimation - bootstrap, Jacknife, the delta method	2
Lec 4	Construction of confidence intervals - classic and boostrap intervals	2
Lec 5	Nonparametric density estimation - histogram and its properties	2
Lec 6	Nonparametric density estimation - kernel estimator and its properties	2
Lec 7	Selection of bandwidth in the kernel estimator	2
Lec 8	Modifications of kernel estimator - variable bandwidth, higher-order kernels	2
Lec 9	Estimation of density through orthogonal expansions	2
Lec 10	Estimation of density - local likelihood function and maximum likelihood method with smoothing	2
Lec 11	Nonparametric regression function estimation - estimation of kernel	2
Lec 12	Selection of the bandwidth and modification of the kernel estimator of regression function.	2
Lec 13	Hazard function estimation - parametric and non-parametric methods.	2

Lec 14	Empirical Bayesian methods - Stein estimator	2
Lec 15	Test	2
	Total hours	**30**

Laboratory		Number of hours
Lab 1	Parametric estimation - method of maximum likelihood. Bias, variance, mean square error - estimation using computer simulations.	4
Lab 2	Estimation of bias, variance and construction of confidence intervals using the method of substitution and replication methods (bootstrap, jackknife). Estimating the quality of estimators based on simulation studies.	4
Lab 3	Estimating the several parameters - asymptotic covariance matrix, the covariance matrix estimation using the method of substitution and replication methods. Estimating the quality of estimators based on simulation studies.	4
Lab 4	Nonparametric estimation of density - the histogram, method of the nearest neighbor, kernel estimator, orthogonal expansions. Smoothing parameter selection. Quality rating based on simulation studies.	6
Lab 5	Nonparametric estimation of the regression function. Estimators: kernel, local polynomial, the nearest neighbor, the smooth spline functions. Construction of confidence intervals and bands using the bootstrap method. Smoothing parameter selection. Quality rating based on simulation studies.	6
Lab 6	Estimation of survival function and hazard function with parametric and nonparametric methods. Construction of confidence intervals through approximation with the normal distribution and the bootstrap method. Quality rating based on simulation studies.	4
Lab 7	Empirical Bayesian methods. Quality assessment using simulation studies.	4
	Total hours	**30**

TEACHING TOOLS USED

1. Lecture problem - computer presentation and traditional method
2. Laboratory - self development of programs for simulation, reports from analyses
3. Consultations
4. Student’s self work – preparation for the laboratory

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	All subject effects of the course	Reports and activity during the laboratory.
F2	PEU_W01	Test

	PEU_W02 PEU_W03 PEU_W04 PEU_W05	
P=0,75*F1+0,25*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] L. Devroye, A Course in Density Estimation [2] B. Efron, R. Tibshirani, Introduction to the Bootstrap [3] B. Silverman, Density Estimation for Statistics and Data Analysis. [4] W. Härdle, Smoothing Techniques with implementation in S [5] A.W.Bowman and A. Azzalini, Applied Smoothing Techniques for Data Analysis, The kernel approach with S-Plus Illustrations [6] P.J. Green and B.W.Silverman, Nonparametric regression and Generalized Linear Models
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr hab. Małgorzata Bogdan (Malgorzata.Bogdan@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name in Polish: Zarządzanie Ryzykiem Finansowym
Name in English: Financial Risk Management
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Financial and Actuarial Mathematics
Level and form of studies: 2nd* level, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5	1,5			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has an elementary knowledge of financial markets and (discrete and continuous) models of financial mathematics

\

SUBJECT OBJECTIVES

C1 Learning and mastery of key concepts and methods in the field of financial mathematics

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the most important models and techniques of financial engineering
PEU_W02 knows the basics of stochastic and numerical modeling in financial engineering
relating to skills:
PEU_U01 can construct mathematical models used in financial engineering
relating to social competences:
PEU_K01 can by himself search for information in the literature, even in foreign languages

PROGRAMME CONTENT		
Form of classes – lecture		**Number of hours**
Lec 1	Fundamental theorems of asset pricing - overview	2
Lec 2	Greek parameters, delta/gamma hedging	2
Lec 3	Volatility modeling	2
Lec 4	Exotic options – overview	4
Lec 5	Stochastic control	2
Lec 6	Risk measures and financial risk	2
Lec 7	Portfolio pricing	2
Lec 8	Construction of optimal portfolio, effectiveness measures of investment portfolio	2
Lec 9	Measuring of default, asset and liability management and hedging strategies, immunization	2
Lec 10	Credit risk management	4
Lec 11	Operational risk management	2
Lec 12	Time variation in risk	2
Lec 13	Backtesting and stress testing	2
	Total hours	**30**
Form of classes - class		**Number of hours**
Cl 1	Illustration of all models.. Analytical and computer methods. Examples of pricing derivatives.	
	Total hours	**30**

TEACHING TOOLS USED

1. Lecture problem - traditional method.
2. Problem and counting exercises.
3. Consultations.
4. Student's self work - preparation for exercises.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_K01	oral responses, tests, small tests
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] [1] A. Weron, R. Weron (1998) Inżynieria finansowa, WNT [2] P. Jorion (2003) Financial risk manager handbook, Wiley. **SECONDARY LITERATURE:** [3] P. Willmott (2006) On Quantitative Finance, Wiley. [4] A. J. McNeil R. Frey, P. Embrechts (2015) Quantitative Risk Management Concepts, Techniques and Tools, Princeton University Press.
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Prof. dr hab. Zbigniew Palmowski (Zbigniew.Palmowski@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name in Polish: Zagadnienia ze swobodnym brzegiem
Name in English: Free boundary problems
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Mathematics for industry and commerce
Profile: academic / practical*
Level and form of studies: 2nd* level, full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical (P) classes	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5	1,5			

*delete as applicable

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has basic knowledge and abilities in the area of ordinary and partial differential equations.

\

SUBJECT OBJECTIVES

C1 Study of mathematical models of phenomena in science and technology leading to free boundary problems.
C2 Study of basic analytical methods in examining free boundary problems.

SUBJECT EDUCATIONAL EFFECTS
relating to knowledge: student PEU_W01 knows basic mathematical models connected with free boundary problems. PEU_W02 knows basic analytical methods in examining free boundary problems. relating to skills: student PEU_U01 can build mathematical models leading to free boundary problems. PEU_U02 can examine free boundary problems. relating to social competences: student PEU_K01 is able to take benefits form scientific literature PEU_K02 knows limitations of his knowledge and understands the need of further education.

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Remaining basic theory of elliptic and parabolic partial differential equations.	2
Lec 2	Stefan problem, notion of the free boundary. Inverse Stefan problem.	2
Lec 3	Free boundary problems in melting and freezing. Modeling of problems connected with phase transition.	4
Lec 4	Modeling of flows in porous media: Boussinesq equation, porous media equation.	2
Lec 5	Self-similar solutions of porous media equation.	2
Lec 6	Free boundary in solutions of porous media equation, finite speed of propagation of disturbances. Retention and penetration property. Large time behavior of solutions.	2
Lec 7	Free boundary in reaction–diffusion–convection equations.	4
Lec 8	Diffusion in solids. Free boundary problems.	2
Lec 9	Modeling of flows in deformable media, spreading of impurities.	4
Lec 10	Free boundary problems in digital image processing.	2
Lec 11	Free boundary problems in financial mathematics.	2
Lec 12	Stationary free boundary problems: dam problem, obstacle problems in calculus of variations.	2
	Total hours	**30**

Classes		**Number of hours**
Cl 1	Solving of problems illustrating theory given on lectures.	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method. N2. Classes – traditional method.

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01 PEU_W02 PEU_K01	Final test
F2	PEU_U01 PEU_U02 PEU_K01 PEU_K02	Oral presentations, tests.
P= 0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] R. M. Mattheij, S. W. Rienstra, J.H.M. ten Thije Boonkkamp, Partial Differential Equations, Modeling, Analysis, Computation, SIAM, Philadelphia 2005

[2] J. Ockendon, S. Howison, A. Lacey & A. Movchan, Applied Partial Differential Equations, Oxford University Press, Oxford 1999.

[3] A. Fasano, Parabolic Free Boundary Problems in Industrial and Biological Applications, SIMAI e-Lecture Notes, Volume 9, 2011

SECONDARY LITERATURE:

[1] V. Alexiades, A.D. Solomon, Mathematical Modeling of Melting and Freezing Processes, Hemisphere – Taylor & Francis, Washington, DC, USA, 1983

[2] J.L. Vazquez, The Porous Media Equation, Mathematical Theory, Clarendon Press, Oxford 2007

A.Friedman, Variational Principles and Free Boundary Problems, John Wiley and Sons, Inc

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. Jan Goncerzewicz (Jan.Goncerzewicz@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD
Name in Polish: MODELE UBEZPIECZENIOWE W PRZEMYŚLE
Name in English: Insurance models for industry
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): FINANCIAL AND ACTUARIAL MATHEMATICS
Level and form of studies: 2nd* level, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic concepts of the stochastic processes
2. Student knows principles of MATLAB numerical computing environment

\

SUBJECT OBJECTIVES

C1 Study of the classical concepts and acquisition of the knowledge of insurance models in industry

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the most important concepts of insurance models in industry
PEU_W02 knows principles of stochastic modeling in actuarial mathematics

relating to skills:
PEU_U01 can construct actuarial models, that can be applied to industry insurance

relating to social competences:
PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Form of classes - lecture		**Number of hours**
Lec 1	Types of insurance policies in industry. Solvency II in Non-Life Insurance.	2
Lec 2	Premium principles, risk measures.	2
Lec 3	Franchises and their types. Pricing of net premiums with franchise.	2
Lec 4	Individual risk model.	2
Lec 5	Approximations for total loss in individual risk model	2
Lec 6	Collective risk model. Frequency and severity distributions of claims. Parameters and distributions of aggregate claim amount.	2
Lec 7	Compound Poisson model. Practical consequences of the theorem on the sum of compund Poisson risk.	2
Lec 8	The (a,b) class of distribution. Mixed Poisson model.	2
Lec 9	Risk proces. The adjustment coefficient. The probability of ruin.	4
Lec 10	Distribution of the maximal aggregate coefficient and ruin probability. Pollaczek-Khinchin formula.	3
Lec 11	Approximations of ruin probability in finite and infinite time horizon	2
Lec 12	System Bonus-Malus	2
Lec 13	Credibility theory	3
	Total hours	**30**

Form of classes - laboratory		**Number of hours**
Lab 1	Solving of problems illustrating theory given in the lectures	30
	Total hours	**30**

TEACHING TOOLS USED
1. Lecture – traditional method 2. Computer laboratory with MATLAB numerical computation environment 3. Consultations 4. Student’s self-work – preparation for the laboratory

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_K01	oral presentations, tests
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] N. L. Bowers i inni, Actuarial Mathematics, The Society of Actuaries, Itasca, Illinois 1997.
[2] P. Cizek, W. Haerdle, R. Weron (red.), Statistical tools for finance and insurance, Springer, Berlin, 2011.

SECONDARY LITERATURE:

[1] E. Banks, Alternative risk transfer, Wiley, 2003.
[2] S. A. Klugman, H. H. Panjer, G. E. Willmot, Loss Models: From Data to Decisions, Wiley, 2012.
[3] H. H. Panjer, G. E. Willmot, Insurance risk models, Society of Actuaries, 1992.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. inż. Krzysztof Burnecki, prof. nadzw. (Krzysztof.Burnecki@pwr.edu.pl)
Dr hab. inż. Agnieszka Wyłomańska, prof. nadzw. (Agnieszka.Wylomanska@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Wprowadzenie do teorii oszczędnego próbkowania
Name of subject in English: Introduction to compressed sensing
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Data engineering
Profile: academic / practical*
Level and form of studies: 2nd level / full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows basic facts of linear algebra and optimization.
2. Knows MATLAB package for numerical computing.

\

SUBJECT OBJECTIVES

C1 Study of theory and basic concepts of compressed sensing.
C2 Study of numerical algorithms for signal recovery used in compressed sensing.
C3 Study of fundamental applications of compressed sensing.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows fundamental theoretical results in compressed sensing
PEU_W02 knows basic algorithms for sparse recovery
PEU_W03 knows classical applications of compressed sensing

relating to skills:
PEU_U01 understand the main idea of compressed sensing
PEU_U02 be able to apply numerical methods for sparse recovery

PEU_U03 be able to demonstrate examples of compressed sensing applications relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature PEU_K02 understands the need for systematic work on course material

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Introduction to compressed sensing. History, motivations and overview of applications.	2
Lec 2	Review of vector spaces.	2
Lec 3	Sparse solutions of undetermined systems.	4
Lec 4	Null space property.	2
Lec 5	Restricted isometry property.	4
Lec 6	Signal recovery by l_1 minimization.	8
Lec 7	Signal recovery algorithms.	4
Lec 8	Examples of applications for one- and two-dimensional data	4
	Total hours	**30**

Laboratory		**Number of hours**
Lab 1	Solving selected problems illustrating theory given in the lectures analytically or using MATLAB package for numerical computing	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method supported by multimedia presentation N2. Computer laboratory – solving problems analytically, working on a computer using MATLAB package for numerical computations N3. Consultations N4. Student’s self work – preparation for the laboratory

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01, PEU_W02, PEU_W03	activity on the laboratory, oral presentation of results

	PEU_U01, PEU_U02, PEU_U03, PEU_K01, PEU_K02	
F2	PEU_W01, PEU_U01, PEU_K01, PEU_K02	test
P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] Ch. Hegde, R. Baraniuk, M. A. Davenport, M. F. Duarte , "An Introduction to Compressive Sensing", 2011. [2] H. Boche, R. Calderbank, G. Kutyniok, J. Vybíral, "Compressed Sensing and its Applications", Birkhaeuser, 2013. **SECONDARY LITERATURE:** [1] J. A. Tropp, S. J. Wright, "Computational Methods for Sparse Solution of Linear Inverse Problems", Proc. IEEE, Vol. 98 No. 5, 2010. [2] O. Scherzer (Editor) „Handbook of Mathematical Methods in Imaging", Springer-Verlag, 2010.
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr Monika Muszkieta (monika.muszkieta@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name in Polish: Wprowadzenie do Problemów Odwrotnych
Name in English: Introduction to Inverse Problems
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Mathematics for industry and commerce, modeling, simulation, opimalization
Profile: academic / practical*
Level and form of studies: 2nd* level, full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical (P) classes	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as applicable

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows basic facts of mathematical analysis.
2. Knows MATLAB package for mathematical computing.

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SUBJECT OBJECTIVES

C1 Study of classical examples of inverse problems.
C2 Study of theory and basic concepts for inverse problems.
C3 Study of numerical methods for solving inverse, ill-posed problems.

SUBJECT EDUCATIONAL EFFECTS
relating to knowledge: PEU_W01 knows the definition of well-posedness PEU_W02 knows classical examples of inverse problems PEU_W03 knows basic methods of regularization PEU_W04 knows numerical methods for solving inverse problems relating to skills: PEU_U01 understand the definition of well-posedness PEU_U02 be able to demonstrate examples of inverse problems PEU_U03 be able to apply numerical methods to solve inverse problems relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature. PEU_K02 understands the need for systematic work on course material

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Introduction to inverse problems. Definition of the well-posedness. Important classes of inverse problems.	2
Lec 2	Differentiation of a noisy data.	2
Lec 3	Computerized tomography. The Radon transform.	2
Lec 4	Inverse problems in image processing.	2
Lec 5	Parameter identification problems.	4
Lec 6	Ill-conditioned matrix equations	2
Lec 7	Regularization of linear ill-posed problems.	4
Lec 8	Tikhonov regularization.	2
Lec 9	Maximum entropy regularization.	2
Lec 10	Total variation regularization.	2
Lec 11	Estimation of the regularization parameters.	2
Lec 12	Iterative regularization	4
	Total hours	**30**

Laboratory		**Number of hours**
Lab 1	Solving problems illustrating the methods given in the lecture using MATLAB package for scientific computing	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method N2. Computer laboratory – working on a computer using MATLAB package for numerical computations N3. Consultations N4. Student’s self work – preparation for the laboratory

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W03, PEU_W04, PEU_U03, PEU_K01, PEU_K02	activity in the laboratory, oral presentation
F2	PEU_W01, PEU_W02, PEU_W03, PEU_W04, PEU_U01, PEU_U02, PEU_U03, PEU_K01, PEU_K02,	test
P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] C. W. Groetsch. “Inverse Problems in the Mathematical Sciences”. Vieweg, Braunschweig, 1993.

[2] C. R. Vogel. „Computational Methods for Inverse Problems”. SIAM, Philadelphia, PA, USA, 2002.

SECONDARY LITERATURE:

[1] H. W. Engl, M. Hanke, and A. Neubauer. “Regularization of Inverse Problems”. Kluwer Academic Publishers, Dordrecht, 1996.

[2] A. A. Samarskii and P. N. Vabishchevich. “Numerical Methods for Solving Inverse Problems of Mathematical Physics”. Walter de Gruyter, 2007.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr Monika Muszkieta (monika.muszkieta@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD
Name of subject in Polish WSTĘP DO STOSOWANEJ DYNAMIKI CIECZY
Name of subject in English INTRODUCTION TO APPLIED FLUID DYNAMICS
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): Mathematics for Industry and Commerce
Level and form of studies: ~~1st~~/ 2nd* level, full-time / ~~part-time*~~
Kind of subject: ~~obligatory~~ / optional / ~~university-wide*~~
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30			30	
Number of hours of total student workload (CNPS)	90			60	
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3			2	
including number of ECTS points for practical classes (P)	2			2	
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5			1,5	

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has the standard knowledge of the classical concepts , theorems and methods of real and complex analysis
2. Student has basic knowledge of concepts and methods of the ordinary differential equations

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SUBJECT OBJECTIVES

C1 Study of the advanced methods of mathematical analysis in mathematical modelling of the dynamics fluid phenomena.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows advanced theorems of the Real and complex analysis related to the fluid dynamics

PEU_W02 has advanced knowledge concerning mathematical analysis: is able to understand formulations of the studied problems related to the fluid dynamics relating to skills: PEU_U01 can construct mathematical models applied in the fluid dynamics relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Lecture		Number of hours
Lec 1	Reminder of the vector analysis elements	2
Lec 2	Reminder of the vector analysis elements	2
Lec 3	Reminder of the complex analysis elements	2
Lec 4	Conformal mappings	2
Lec 5	Laws of conservation	2
Lec 6	Equations of motion for an ideal fluid	2
Lec 7	Elementary viscous flow	2
Lec 8	Waves	2
Lec 9	Waves	2
Lec 10	Shock waves modelling	2
Lec 11	Classical aerofoil theory	2
Lec 12	Classical aerofoil theory	2
Lec 13	Nonlinear models in diffusion phenomena	2
Lec 14	Boundary layers	2
Lec 15	Computational fluid dynamics (CFD)	2
	Total hours	**30**

Project		Number of hours
Pr 1	Preparation and presentations of projects illustrating theory given in the lectures.	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method and presentations N2. Student partial project presentation and final presentation

N3. Consultations N4. Student’s self work – work on the project development

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_K01	Partial project presentations, final project presentation
C P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] B. J. Acheson, Elementary Fluid Dynamics.
[2] H.Ockendon, A.B.Tayler, Inviscid Fluid Flows.

SECONDARY LITERATURE:

[1] J.D. Logan, Applied Mathematics. A Contemporary Approach.
[2] K. Ericsson, D. Estep, P. Hansbo, C. Johnson, Computational Differential Equations.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr inż. Łukasz Płociniczak (Lukasz.Plociniczak@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name in Polish WSTĘP DO ANALIZY DUŻYCH WOLUMENÓW DANYCH
Name in English INTRODUCTION TO BIG DATA ANALYTICS
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): DATA ENGINEERING
Level and form of studies: ~~1st~~/ 2nd* level, ~~uniform magister studies*~~, full-time / ~~part-time*~~
Kind of subject: ~~obligatory~~ ~~/~~ optional ~~/ university-wide*~~
Subject code
Group of courses YES ~~/ NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)			4		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	3				

*delete as applicable

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has basic programming skills.

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SUBJECT OBJECTIVES

C1 Searching, extracting, storing and computer-aided analysis of big data. Understanding its impact and relevance in today's society.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W12 knows how to use programming languages and their scientific modules for big data analysis

relating to skills: PEU_U12 can perform an analysis of big data by making use of a computer relating to social competences: PEU_K06 can, without assistance, search for necessary information in the literature, also in foreign languages PEU_K02 can accurately formulate questions for deeper understanding of a given topic

PROGRAMME CONTENT		
:ecture		Number of hours
Lec1	Introduction to Big Data	2
Lec2	Big data platforms	2
Lec3	Hadoop ecosystem	4
Lec4	Querying big data with Hive	4
Lec5	Big data and machine learning	4
Lec6	In-memory big data platform - Spark	4
Lec7	Linked Big Data	4
Lec8	Big data visualization	2
Lec9	Project presentations	4
	Total hours	**30**

Form of classes - project		Number of hours
Pr1	Practical Preparation and presentations of projects illustrating methods given in the lectures.	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method and presentations N2. Student partial project presentation and final presentation N3. Consultations N4. Student’s self work – work related to the project development

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W12 PEU_U12	mid-term exams
F2	PEU_U12 PEU_K06 PEU_K02	Oral presentations
C P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] Flach, Peter, Machine Learning, Cambridge University Press, 2012

[2] Holmes, Alex, Hadoop in practice, Manning Publications, 2013

[3] Provost, Foster, Facett, Tom, Data Science for Business. What you need to know about data mining and data-analytic thinking, O’Reilly, 2013

[4] Loshin, David, Big Data Analytics. From Strategic Planning to Enterprise Integration with Tools, Techniques, NoSQL, and Graph, Morgan Kaufmann, 2013

SECONDARY LITERATURE:

[5] http://hadoop.apache.org/, http://spark.apache.org/, http://storm.apache.org/, http://kafka.apache.org/

[6] deRoos, Dirk, Hadoop for Dummies, For Dummies, 2014

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: MODELE UBEZPIECZEŃ ŻYCIOWYCH
Name of subject in English: Life insurance models
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): Financial and Actuarial Mathematics
Profile: academic / ~~practical~~*
Level and form of studies: 1st/ 2nd level, uniform magister studies*, full-time / part-time*
Kind of subject: obligatory / optional / university-wide*
Subject code
Group of courses YES / NO*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	Examination / ~~crediting with grade~~*				
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5	1,5			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic concepts of the probability theory

SUBJECT OBJECTIVES

C1 Study of the classical concepts and acquisition of the knowledge of life insurance mathematics

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the most important concepts of life insurance mathematics
PEU_W02 knows principles of stochastic modeling in life insurance mathematics

relating to skills:
PEU_U01 can construct mathematical models used in life insurance mathematics

relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Fundamental concepts of life insurance mathematics	6
Lec 2	Introduction to the course, survey over provision types.	2
Lec 3	Net reserves in life insurance.	4
Lec 4	Decomposition of the loss random variable (Hattendorff's theorem).	2
Lec 5	Technical gain.	3
Lec 6	Gross reserves in life insurance, Zillmer's reserve	2
Lec 7	Multiple decrement model: net premiums and reserves	3
Lec 8	Multiple life insurance: net premiums and reserves	6
Lec 9	Solvency II - technical provisions, best estimate, risk margin, technical provisions for accounting purposes	2
	Total hours	**30**

Classes	**Number of hours**
Solving of problems illustrating theory given in the lectures, solving of problems from actuarial exams	**30**
Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method. N2. Problem-solving classes. N3. Consultations. N4. Student's self-work – preparation for the classes.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_K01	oral presentations, tests
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
<u>PRIMARY LITERATURE:</u>
[1] N. L. Bowers i inni „Actuarial Mathematics”, The Society of Actuaries, Itasca, Illinois 1997 [2] H. U. Gerber „Life insurance mathematics”, Springer-Verlag, Berlin 1997 [3] D. Dickson, M. Hardy, H. Waters „Actuarial mathematics for life contingent risks” 2nd ed.; Cambridge University Press, Cambridge 2013
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr hab. inż. Krzysztof Burnecki, prof. nadzw. (Krzysztof.Burnecki@pwr.edu.pl) **Dr hab. inż. Agnieszka Wyłomańska, prof. nadzw.** (Agnieszka.Wylomanska@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name in Polish: Maszynowe uczenie
Name in English: Machine learning
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Data Engineering
Level and form of studies: 2nd* level, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Programming skills
2. Know the basics of logic

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SUBJECT OBJECTIVES

C1 Familiarize students with different approaches and tasks of inductive learning
C2 Familiarize students with supervised and unsupervised learning
C3 Ability to choose the method for a given task
C4 Understanding the role of data quality in machine learning

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 Student knows the methods of supervised learning
PEU_W02 Student knows unsupervised learning methods
PEU_W03 Student knows the role of data and how to prepare them for a given task of inductive learning
relating to skills:
PEU_U01 Student knows how to select a method for a given task
PEU_U02 Student is able to prepare data for inductive learning task
PEU_U03 Student is able to properly analyze the results of inductive learning

relating to social competencies: PEU_K01 Student is able to analyze the results of induction learning together with others

PROGRAMME CONTENT		
Form of classes – lecture		**Number of hours**
Lec 1	Introduction to the course. Basic concepts, types of machine learning, examples	2
Lec 2	Learning, Generalization, VC dimension	2
Lec 3	Supervised learning - Classification, Regression. Classification measures Learning using the Version Space	2
Lec 4	Classification - induction of a set of rules (ILA, AQ, and / or other algorithms)	2
Lec 5	Decision tree generation methods, inference in decision trees	2
Lec 6	Dimensional reduction methods	2
Lec 7	Neural networks	2
Lec 8	Overfitting, Regularization, Validation	2
Lec 9	SVM and kernel	2
Lec 10	Ensemble of Classifiers, Bagging and boosting	2
Lec 11	Multi-class classification and multi-label classification, example: image annotation	2
Lec 12	Unsupervised Learning - Clustering. Clustering Ensembles	2
Lec 13	Data mining process - an idea, tasks. Frequent Patterns. Exemplary methods, e.g.: A-Priori algorithm	2
Lec 14	Evolutionary computation in data mining tasks	2
Lec 15	Test	2
	Total hours	**30**

Form of classes - laboratory		**Number of hours**
Lab 1	Introductory classes, description of tasks, conditions of credit.	2
Lab 2	Get acquainted with selected environments: Weka, R, Python	2
Lab 3	Exercise 1: A comparison of selected classifiers	2

Lab 4	Continuation of Exercise 1	2
Lab 5	Presentation of Exercise 1 for evaluation	2
Lab 6	Exercise 2: Impact of attributes selection on classification quality - filter and wrapper approaches	2
Lab 7	Continuation of Exercise 2	2
Lab 8	Presentation of Exercise 2 for evaluation	2
Lab 9	Exercise 3: Ensemble of Classifiers - Selected Decision Making Techniques	2
Lab10	Continuation of Exercise 3	2
Lab11	Presentation of Exercise 3 for evaluation	2
Lab 12	Exercise 4: Generation of association rules, analysis of the method properties	2
Lab 13	Continuation of Exercise 4	2
Lab 14	Presentation of Exercise 4 for evaluation	2
Lab 15	Summarization of lectures	2
	Total hours	**30**

TEACHING TOOLS USED
1. Knowledge presentations using the projector. 2. Audiovisual media in the demos versions presentation. 3. Searching and study of scientific literature in the WRUT Library.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01, PEU_W03,	test
F2	PEU_U01 – PEU_U03, PEU_K02	Rating for lab exercises
F3	PEU_W02, PEU_W03	test
F4	PEU_U04, PEU_K01	participation in the discussion of the exercises results
P1	PEU_W01-W03	test grade
P2	PEU_U01 – PEU_U03, PEU_K02	Final score of laboratory based on the sum of points scored for each exercise
P=(P1+P2)/2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] “Introduction to Machine Learning”. Second Edition. Ethem Alpaydın. The MIT Press Cambridge, Massachusetts London, England, 2010. [2] „Systemy uczące się”. Cichosz Paweł. WNT, 2009. [3] „Mining of Massive Datasets”. Jure Leskovec, Stanford Univ.; Anand Rajaraman, Milliway Labs; Jeffrey D. Ullman, Stanford Univ. Copyright c 2010, 2011, 2012, 2013, 2014 Anand Rajaraman, Jure Leskovec, and Jeffrey D. Ullman **SECONDARY LITERATURE:** [1] “Automating the Design of Data Mining Algorithms. An Evolutionary Computation Approach”, Natural Computing Series. Gisele L. Pappa and Alex A. Freitas. Springer-Verlag Berlin Heidelberg 2010. [2] “Machine Learning”, Tom Mitchell, McGraw Hill, 1997. [3] “A Course in Machine Learning”, Hal Daumé III, Copyright © 2012 Hal Daumé III
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Halina Kwaśnicka (halina.kwasnicka@pwr.edu.pl)

Zał. nr 5 do ZW 16/2020

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Matematyczne przetwarzanie obrazów
Name of subject in English: Mathematical Image Processing
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): MODELLING, SIMULATION, OPTIMIZATION
Profile: academic / practical*
Level and form of studies: 2nd level/ full-time
Kind of subject: optional
Subject code MAT001582
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Knows basic concepts of theory of partial differential equations
2. Knows MATLAB package for mathematical computing

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SUBJECT OBJECTIVES

C1 Study of mathematical models in image processing.
C2 Study of numerical methods for solving problems in image processing.
C3 Application of acquired knowledge to construction and analysis of mathematical models in image processing

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows basic models for image restoration
PEU_W02 knows basic variational models for image segmentation
PEU_W03 knows numerical methods for solving problems in image processing

relating to skills:
PEU_U01 be able to demonstrate the difference between known models of image restoration

PEU_U02 be able to demonstrate the difference between known models of image segmentation PEU_U03 be able to apply numerical methods to solve mathematical problems in image processing relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature. PEU_K02 understands the need for systematic work on course material

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Overview of fundamental problems in image processing. Representation of images. Models of image degradation.	2
Lec 2	Linear diffusion filter. Gaussian smoothing in the frequency domain.	2
Lec 3	Nonlinear diffusion filters. Isotropic and anisotropic diffusion models.	4
Lec 4	Discretization of the nonlinear diffusion filter.	2
Lec 5	Introduction to variational models for image restoration.	2
Lec 6	Image denoising by total variation regularization.	2
Lec 7	First order numerical schemes for total variation minimization.	4
Lec 8	Image deblurring model.	2
Lec 9	Total variation model for image inpainting.	2
Lec 10	The Mumford-Shah model for image segmentation and its approximations.	4
Lec 11	Active contours model for image segmentation.	4
	Total hours	**30**

Laboratory		**Number of hours**
Lab 1	Basic operation on images. Degradation of images. Gaussian smoothing.	4
Lab 2	Solving selected problems illustrating theory given in the lectures using mathematical MATLAB package for numerical computing	26
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method supported by multimedial presentation N2. Computer laboratory – working on a computer using MATLAB package for numerical computations N3. Consultations N4. Student's self work – work on the project

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P –	Educational effect number	Way of evaluating educational effect achievement

concluding (at semester end)		
F1	PEU_W01, PEU_W02, PEU_W03, PEU_U01, PEU_U02, PEU_U03, PEU_K01, PEU_K02,	activity in the laboratory
F2	PEU_W01, PEU_W02, PEU_W03, PEU_U01, PEU_U02, PEU_U03, PEU_K01, PEU_K02,	oral presentation, report
P==0.2*F1+0.8*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] G. Aubert and P. Kornprobst „Mathematical Problems in Image Processing: Partial Differential Equations and the Calculus of Variations", Springer-Verlag, 2007.

[2] T. Chan and J. Shen „Image Processing and Analysis: Variational, PDE, Wavelet, and Stochastic Methods", SIAM, 2006.

SECONDARY LITERATURE:

[1] O. Scherzer (Editor) „Handbook of Mathematical Methods in Imaging", Springer-Verlag, 2010.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr Monika Muszkieta (monika.muszkieta@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD
Name of subject in Polish METODY NIELINIOWE
Name of subject in English NONLINEAR METHODS
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): MATHEMATICS FOR INDUSTRY AND COMMERCE
Level and form of studies: ~~1st~~/ 2nd* level, full-time / ~~part-time*~~
Kind of subject: ~~obligatory~~ / optional / ~~university-wide*~~
Subject code
Group of courses YES / ~~NO*~~

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has knowledge of concepts, theorems and methods of mathematical analysis

2. Student has knowledge of concepts and methods of differential equations

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SUBJECT OBJECTIVES

C1 Study basic concepts and nonlinear methods used in applications

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 has advanced knowledge concerning nonlinear methods
PEU_W02 knows numerical methods applied for approximate solving of mathematical problems in applied sciences
relating to skills:
PEU_U01 is able to construct mathematical models in advanced applications of mathematics
relating to social competences:

PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Lecture		Number of hours
Lec 1	Examples of nonlinear phenomena	2
Lec 2	Examples of nonlinear phenomena	2
Lec 3	Nonlinear oscillators	2
Lec 4	Bifurcation and stability	2
Lec 5	Van der Pol equation	2
Lec 6	Duffig equation	2
Lec 7	2-D systems of nonlinear equations – equilibrium points	2
Lec 8	Classification of the equilibrium points	2
Lec 9	Systems of nonlinear equations - attractors	2
Lec 10	Lorenc equation	2
Lec 11	Strange attractors	2
Lec 12	Belolusov-Zabotynski equation	2
Lec 13	Benard cells – equations of hydrodynamics	2
Lec 14	Examples of nonlinear optimisation	2
Lec 15	Some methods of nonlinear optimisation	2
	Total hours	**30**

Laboratory		Number of hours
Lab 1	Solving of problems illustrating theory given in the lectures by analytic methods and with MATLAB	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method N2. Laboratory- solving problems with computers N3. Consultations N4. Student's self work – preparation for the laboratory

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during	Learning outcomes code	Way of evaluating learning outcomes achievement

semester), P – concluding (at semester end)		
F1	PEU_W01 PEU_W02	test
F2	PEU_U01 PEU_K01	oral answers, calculus trainings, presentations, short tests, tests
P==0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] D.W. Jordan, P. Smith, Nonlinear Ordinary Differential Equations [2] G. Nicolis, Introduction to Nonlinear Science. **SECONDARY LITERATURE:** [1] D. P. Bertsekas, Nonlinear Programming
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Prof. dr hab. Wojciech Okrasiński (Wojciech.Okrasinski@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Metody numeryczne w równaniach różniczkowych
Name of subject in English Numerical methods in differential equations
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Mathematics for Industry and Commerce
Profile: academic / practical*
Level and form of studies: 2nd level/ full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1.5		1.5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has basic knowledge and abilities on mathematical analysis.
2. Student has basic knowledge concerning programming environments: Matlab/Mathematica/Mapple.

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SUBJECT OBJECTIVES

C1 Study of basic notions and knowledge in the area of numerical methods applied in differential equations
C2 Study of basic numerical techniques used in discretization of differentia equations.
C3 Acquisition of basis abilities in construing and analyzing difference schemes for differential equations

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge student:
PEU_W01 knows the most important numerical techniques used in solving problems for differential equations
PEU_W02 knows bases of construing own numerical schemes
relating to skills student:

PEU_U01 is able to analyze basic problems in differential equations with respect to application of suitable approximate methods
PEU_U02 is able to construct mathematical models used in concrete applications of mathematics, based on differential equations and their discrete forms.
…
relating to social competences:
PEU_K01 can, without assistance, search for necessary information in the literature
PEU_K02 understands necessity of systematic and individual work on the material of the course.
relating to skills:
PEU_U01
PEU_U02
…
relating to social competences:
PEU_K01
PEU_K02

PROGRAMME CONTENT

	Lecture	**Number of hours**
Lec 1	Recalling basic facts of theory of ordinary differential equations.	2
Lec 2	Explicit and implicit Euler method of approximate solving of ordinary differential equations and their systems.	2
Lec 3	Runge-Kutta type methods and other schemes of approximation of ordinary differential equations and their systems.	2
Lec 4	Multi-step methods, stability of numerical methods. Stiff problems.	2
Lec 5	Methods of approximation of boundary value problems for second order ordinary differentia equations: shooting methods and difference methods.	2
Lec 6	Methods of approximation of boundary value problems for second order ordinary differentia equations: Ritz-Galerkin method.	2
Lec 7	Difference methods for first order partial differentia equations. CFL condition.	2
Lec 8	Recalling basic facts of theory of second order partial differential equations.	2
Lec 9	Difference approximation of elliptic boundary value problems on the plane.	2
Lec 10	Variational formulation of boundary value problems for elliptic type equations.	2
Lec 11	Ritz-Galerkin and finite element methods for elliptic problems.	2
Lec 12	Difference methods for parabolic problems. Explicit and implicit schemes for heat conduction equation.	2
Lec 13	Stability of approximate method. Cranck-Nicholson scheme for equations of parabolic type.	2
Lec 14	Difference methods for the vibrating string problem and other hyperbolic problems.	4
	Total hours	**30**

	Laboratory	**Number of hours**

Lab 1	Computer construction of solution of ordinary differentia equations.	4
Lab 2	Practical verifying of efficacy of automatic exactness control.	2
Lab 3	Visualization and comparison of usefulness of various methods.	4
Lab 4	Algorithms for numerical methods of solution of one-dimensional boundary value problems for elliptic equations.	4
Lab 5	Discretisation of hyperbolic first order problems. Conditions of stability and convergence of approximate methods.	4
Lab 6	Discretization of two-dimensional boundary value problem for elliptic equations.	4
Lab 7	Difference schemes of approximation of one-dimensional parabolic equation.	4
Lab 8	Difference method of discretization of the vibrating string equation.	4
	Total hours	**30**

TEACHING TOOLS USED

N1. Lecture – traditional method.
N2. Problem and computing laboratory – traditional and using computers method.
N3. Consultations.
N4. Student's personal work – preparation for the laboratory.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	Presentation of given problems.
F2	PEU_U01 PEU_U02 PEU_K01	Oral presentations, tests.
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] Richard L. Burden, J. Douglas Faires, Numerical Analysis.
[2] R. M. Mattheij, S. W. Rienstra, J.H.M. ten Thije Boonkkamp, Partial differential equations. Modeling, analysis and computations.
[3] Stig Larsson, Vidar Thomee, Partial differential equations with numerical methods.

SECONDARY LITERATURE

[1] L. Lapidus, G. F. Pinder, Numerical solution of partial differential equations in science and engineering, John Wiley & Sons, 1998
[2] R. J. Le Vegue, Numerical Methods for conservation laws, Birkhauser, Basel 1990
[3] J. W. Thomas, Numerical partial differential equations: conservation laws and elliptic equations, Springer, New York 1999

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. Wojciech Mydlarczyk (Wojciech.Mydlarczyk@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name of subject in Polish Badania Operacyjne
Name of subject in English Operations Research
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): MODELLING, SIMULATION, OPTIMIZATION
Profile: academic / practical*
Level and form of studies: ~~1st/~~ 2nd level, ~~uniform magister studies~~*, full-time / ~~part-time~~*
Kind of subject: ~~obligatory~~ / optional / ~~university-wide*~~
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	Crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	1		3		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	3				

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic notions of linear algebra and logic.
2. Student knows basics of computer programming.

SUBJECT OBJECTIVES

C1 Learning of basic mathematical models supporting decision-making.
C2 Learning of basic algorithms used in operations research
C3 Acquisition of abilities in constructing mathematical models for real problems.
C4 Acquisition of abilities in implementing models in a mathematical modeling language
C5 Acquisition of abilities in presenting and interpreting solutions of the constructed models.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge the student:
PEU_W01 has in-depth knowledge of linear programming
PEU_W02 knows basic models and algorithms used in operations research.

relating to skills the student:
PEU_U01 can build mathematical models for real problems
PEU_U02 can implement mathematical models using a mathematical modeling language

relating to social competences the student:
PEU_K01 can present problem solutions to non-mathematicians in an understandable way.

PROGRAMME CONTENT

	Lecture	Number of hours
Lec1	Introduction to operations research. Formulation of the linear programming problem	2
Lec2	Building mathematical models (1)	2
Lec3	Building mathematical models (2)	2
Lec4	Building mathematical models (3)	2
Lec5	The simplex algorithm for linear programming.	2
Lec6	Duality and sensitivity analysis in linear programming	2
Lec7	Algorithms for integer linear programming.	2
Lec8	Minimum cost flow problem – applications and mathematical properties	2
Lec9	Network simplex algorithm	2
Lec10	The shortest (longest) path problem – applications and algorithms	2
Lec11	The maximum flow problem – applications and algorithms	2
Lec12	The assignment, minimum spanning tree and traveling salesperson problems – applications and algorithms	2
Lec13	Elements of computational complexity, NP-hard combinatorial optimization problems and limitations of modern computational techniques.	2
Lec14	Multiobjective programming	2
Lec15	Written test	
	Total hours	**30**

	Laboratory	Number of hours
La1	Introduction to MathProg (AMPL) language	2
La2	Building and implementing linear programming models for chosen problems	4
La3	Building and implementing integer linear programming models for chosen problems	8

La4	Building and implementing models for the minimum cost flow problem and its variants	4
La5	Building and implementing models for various variants of the traveling salesperson problem	2
La6	Building and implementation models for chosen combinatorial optimization problems	4
La7	Building and implementing models for chosen multiobjective problems	4
La8	Written test	2
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – computer presentation and traditional method N2. Laboratory – building models for chosen problems and implementation of the models using the AMPL language

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02	Written test (lecture)
F2	PEU_U01 PEU_U02 PEU_K01	Written test (laboratory)
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] H. A. Taha. Operations research. An introduction. Pearson Eduction 2007.
[2] F.S. Hillier, G. J. Lieberman. Introduction to operations research. Mc. Graw Hill 2001.
[3] B. Kolman, R.E. Beck. Elementary linear programming with applications. Elsevier Science 1995.

SECONDARY LITERATURE:

[4] A. Shrijver. Theory of linear and integer programming. J. Wiley & Sons 1999.
[5] M.S. Bazaraa, J. J. Jarvis, H. D. Sherali. Linear programming and network flows. J. Wiley & Sons 2010.
[6] R. Ahuja, T. Magnanti, J. Orlin. Network flows. Theory algorithms and applications. Prentice Hall 1993.
[7] R. Fourer, D.M. Gay, B.W. Kernighan. AMPL. A modeling language for mathematical programming, free e-book: *http://ampl.com/resources/the-ampl-book/chapter-downloads/*

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. inż. Adam Kasperski (adam.kasperski@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD
Name of subject in Polish: Optymalne sterowanie
Name of subject in English: Optimal control
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): MODELLING, SIMULATION, OPTIMIZATION
Level and form of studies: ~~1st/~~ 2nd level, ~~uniform magister studies~~*, full-time / ~~part-time~~*
Kind of subject: ~~obligatory /~~ optional ~~/ university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	1		3		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	3				

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. The student has basic knowledge of calculus, algebra and the probability theory.

SUBJECT OBJECTIVES

C1 Understanding the concepts and methods of control.
C2 Understanding the wording optimal control tasks.
C3 Knowledge of the backgrounds for the analysis of dynamic systems.
C4 Understanding models and analysis of stochastic control systems.
C5 Application of acquired knowledge to create and analyze mathematical models to solve theoretical and practical problems in various fields of science and technology.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge the student:
PEU_W01. Student knows the formulation of operational research problems.
PEU_W02. He recognizes situations that require the application of operations research methods to solve practical problems.
PEU_W03. He knows the limitations of analytical methods and the possibility of numerical analysis of dynamic models.
PEU_W04. He knows the stochastic methods in operations research.

relating to skills the student:
PEU_U01. Student is able to formulate modeling task for analysis in a convenient form.
PEU_U02. He can use the appropriate algorithm to solve tasks in the operational research.
PEU_U03. Student is able to recognize issues that competent optimization methods are based on the use of stochastic camera.

relating to social competences the student:
PEU_U01 The student is able to find and use the recommended literature course and independently acquire knowledge
PEU_U02 The student is able to use the basic tools for the analysis of mathematical models
PEU_U03 The student understands the need for systematic and independent work on mastery of course material.

PROGRAMME CONTENT

Lectures		H ours load
Lec1	Deterministic control system with discrete time. Algorithm of dynamic programming.	2
Lec2	Processes with discrete time. Markov chains. Conditional expectation. Martingales and Markov times.	2
Lec3	Markov decision processes. Bellman equation.	2
Lec4	Introduction to models with infinite horizon. Markov decision models with discounted payments, minimizing the average cost per unit and other criteria.	4
Lec5	Applications Markov decision processes in the reliability theory, the renewal theory, the queue theory.	2
Lec6	Optimal control of the continuous time. The Hamilton-Jacobi-Bellman equation.	2
Lec7	Linear systems with quadratic cost function and a complete state observation. The inventory control systems.	2
Lec8	Systems with uncertain state observation. Iterative determination of the value functions.	2
Lec9	The approximated solution of the Bellman equation.	2
Lec10	Optimal stopping of finite sequences.	2
Lec11	Optimal stopping of finite Markov sequences. Examples.	2
Lec12	Infinite horizon optimal stopping problem.	2
Lec13	The disorder detection problem.	2
Lec14	Suboptimal solutions of operation models. Adaptive systems.	2
	Total hours	30

Laboratory		Number of hours
La1	Examples of deterministic control systems with discrete time.	2
La2	Properties of Markov chains and their analysis. Checking stationarity and ergodicity of stochastic sequences. Classification of states. Conditional expectation. Martingales and Markov moments.	2

La3	Markov decision process for selected practical problems. Analysis of the Bellman equation for the constructed MDPs.	2
La4	Investigation of infinite horizon models. Markov decision models with discounted payoffs, the average cost per unit, and other criteria.	4
La5	Applications Markov decision processes in the reliability theory, the renewal theory, the queue theory-examples.	2
La6	Optimal control of the continuous time. The Hamilton-Jacobi-Bellman equation.	2
La7	Linear systems with quadratic cost function and a complete state observation. The inventory control systems.	2
La8	Systems with uncertain state observation. Iterative determination of the value functions.	2
La9	The approximated solution of the Bellman equation.	2
La10	Optimal stopping of finite sequences.	2
La11	Optimal stopping of finite Markov sequences. Examples.	4
La12	Analysis of selected disorder problems.	2
La13	Suboptimal solutions. Adaptive systems.	2
	Total hours	30

TEACHING TOOLS USED

N1. Lecture - traditional method.
N2. Exercise and accounting problems - the traditional method.
N3. Consultation.
N4. Student's own work - preparing to exercise and test.

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01, PEU_W02, PEU_W03 PEU_W04, PEU_W05 PEU_K01, PEU_K02	oral presentations, quizzes, tests
F2	PEU_W01, PEU_W02, PEU_W03 PEU_W04, PEU_W05 PEU_U01, PEU_U02, PEU_U03, PEU_U04 PEU_K01, PEU_K02, PEU_K03	exam
P=0,4*F1+0,6*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[2] Dimitri P. Bertsekas, Dynamic Programming and Optimal Control, vol. 1, Athena Scientific, Belmont, MA: 2005.
[3] Dimitri P. Bertsekas, Dynamic Programming and Optimal Control, vol. 2, Athena Scientific, Belmont, MA: 2007.
[4] Harold Kushner: Wprowadzenie do teorii sterowania stochastycznego. WNT, 1983.

[5] A.N. Shiryaev. Optimal Stopping Rules. Springer-Verlag, New York, Heidelberg, Berlin, 1978.

SECONDARY LITERATURE:

[1] J. P. Aubin, Optima and Equilibria. An Introduction to Nonlinear Analysis, Springer, Berlin 1993.
[2] Wayne l. Winston: introduction to mathematical programming: applications and algorithms, 1991.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

Dr hab. inż. Anna Jaśkiewicz
Prof. Dr Hab. Eng. Krzysztof Szajowski (krzysztof.szajowski@pwr.edu.pl)

Zał. nr 5 do ZW 16/2020

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish Teoria optymalizacji
Name of subject in English Optimization Theory
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): MODELLING, SIMULATION, OPTIMIZATION
Profile: academic / ~~practical~~*
Level and form of studies: ~~1st~~/ 2nd level, ~~uniform magister studies~~*, full-time / ~~part-time~~*
Kind of subject: obligatory / ~~optional~~ / ~~university-wide~~*
Subject code MAT001588
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	90			
Form of crediting	Examination / ~~crediting with grade~~*				
For group of courses mark (X) final course	X				
Number of ECTS points	3	3			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5	1,5			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Algebra, Mathematical analysis

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SUBJECT OBJECTIVES

C1 Student is understanding the concepts and methods of mathematical programming.
C2 He knows and understands the formulation of the linear and quadratic programming.
C3 He has knowledge of the theoretical background of mathematical programming.
C4 He knows the computer methods of mathematical programming.
C5 He is able to apply the acquired knowledge to create and analyze mathematical models to solve theoretical and practical study in various fields of science and technology.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 Student knows the formulation of mathematical programming problems.
PEU_W02 He has a basic knowledge about the usage and importance of mathematical programming methods.
PEU_W03 He knows the limitations of analytical methods and the possibility of numerical analysis of optimization problems.
relating to skills:
PEU_U01 Student is able to formulate mathematical programming problem in a convenient

form for analysis.
PEU_U02 He can use the appropriate algorithm to solve tasks in the mathematical programming.
PEU_U03 He can apply optimization methods, and analytical methods or numerical analysis, in order to solve practical problems.
relating to social competences:
PEU_K01 The student is able to find and use the recommended literature course and independently acquire knowledge.
PEU_K02 The student is able to use the basic tools for the analysis of mathematical models.
PEU_K03 The student understands the need for systematic and independent work on mastery of course material.

PROGRAMME CONTENT

	Lecture	Number of hours
Lec 1	Introduction to mathematical programming. Optimization without constraints. Global and local extremes. Optimality conditions.	2
Lec 2	Gradient methods. Steepest descent method. Newton's method and its variants. Analysis of convergence.	6
Lec 3	Linear programming. Geometric interpretation. Simplex algorithm.	4
Lec 4	Dual problem. Duality theory for linear programming. Sensitivity analysis.	2
Lec 5	Integer programming. Linear programming relaxation. Branch and bound method.	2
Lec 6	The theory of Lagrange multipliers. The necessary and sufficient conditions for extreme for constraints in the equality form. Lagrange multipliers in sensitivity analysis.	2
Lec 7	Constraints in the form of inequality. Optimality conditions of Karush-Kuhn-Tucker.	2
Lec 8	Quadratic programming.	2
Lec 9	Quadratic penalty function method. The method of multipliers.	2
Lec 10	Optimization on a convex set. Frank-Wolfe’s method. Gradient projection method. Barrier method,	4
Lec 11	Convex programming. Duality for convex programming. Subgradient. Subgradient methods.	2
	Total hours	30

	Classes	Number of hours
Cl 1	Necessary and sufficient optimality conditions.	4
Cl 2	Properties of convex functions and convex sets.	2
Cl 3	Illustration of gradient methods.	4
Cl 4	Simplex method. Practical applications of linear programming. Sensitivity analysis.	6
Cl 5	Branch and bound method. Practical applications of integer programming.	4
Cl 6	Applications of Lagrange multiplier theory in practical optimization problems.	6
Cl 7	General constrained optimization algorithms.	4
	Total hours	30

Laboratory		Number of hours
Lab 1		
Lab 2		
Lab 3		
Lab 4		
Lab 5		
…		
	Total hours	

Project		Number of hours
Proj 1		
Proj 2		
Proj 3		
Proj 4		
…		
	Total hours	

Seminar		Number of hours
Semin 1		
Semin 2		
Semin 3		
…		
	Total hours	

TEACHING TOOLS USED
N1. Lecture - traditional method. N2. Exercise and accounting problems - the traditional method. N3. Computer-assisted homeworks. N4. Student's own work - preparing to exercise and test.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01, PEU_W02, PEU_W03, PEU_K01, PEU_K02	oral presentations, quizzes, homeworks
F2	PEU_W01, PEU_W02, PEU_W03, PEU_U01, PEU_U02, PEU_U03, PEU_K01, PEU_K02, PEU_K03	exam
P=0,4*F1+0,6*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] D.P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, MA: 1999. [2] S.P. Bradley, A.C. Hax, T.L. Magnanti, Applied Mathematical Programming, Addison-Wesley Publishing Company, 1977. [3] A. Cegielski, Programowanie matematyczne cz.. 1. Programowanie liniowe, Wydawnictwo Uniwersytetu Zielonogórskiego, 2002 [4] A. Antoniou, W.-S. Lu, Practical Optimization, Springer Science+Business Media, LLC, 2007. **SECONDARY LITERATURE:** [1] S. Boyd, L. Vanderberghe, Convex Optimization, Cambridge University Press, 2004. [2] I. Nykowski, Programowanie liniowe, PWE Warszawa 1980. [3] W. Grabowski, Programowanie matematyczne, PWE Warszawa 1980. [4] R.S. Garfinkel, G.L. Nemhauser, Programowanie całkowitoliczbowe, PWN, 1978. [5] D.P. Bertsekas, A. Nedic, A.E. Ozdaglar, Convex Analysis and Optimization, Athena Scientific, Belmont, MA: 2003. [6] A. Ruszczyński, Nonlinear optimization, Princeton University Press, Princeton, NJ, 2006.
SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)
Dr hab. inż. Piotr Więcek (Piotr.wiecek@pwr.edu.pl)

FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD

Name in Polish: Równania różniczkowe cząstkowe z zastosowaniami w fizyce i przemyśle
Name in English: Partial differential equations with applications in physics and industry
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): MATHEMATICS FOR INDUSTRY AND COMMERCE
Level and form of studies: ~~1st/~~ 2nd* level, full-time / ~~part-time~~*
Kind of subject: obligatory ~~/ optional / university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	120	60			
Form of crediting	Examination / ~~crediting with grade~~*	Examination / crediting with grade*	Examination / crediting with grade*	Examination / crediting with grade*	Examination / crediting with grade*
For group of courses mark (X) final course	X				
Number of ECTS points	3	3			
including number of ECTS points for practical classes (P)		4			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1	2			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply classical notions and methods of real and complex analysis.
2. Student knows and can apply elementary notions and methods of ordinary differential equations.

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SUBJECT OBJECTIVES

C1 Study of basic notions and acquisition of knowledge in the area of differential equations.
C2 Study of basic applications of partial differential equations in science, technology and industry.
C3 Acquisition of basic abilities in mathematical modelling by partial differential equations.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge the student:

PEU_W01 knows the most important theorems from main areas of differential equations

PEU_W02 knows basics of modelling by differential equations in technology and natural sciences, especially in physics, chemistry and biology.

relating to skills the student:

PEU_U01 can analyze basic problems of differential equations,

PEU_U02 can construct mathematical models with the usage of differential equations in concrete applications of mathematics.

relating to social competences the student:

PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PEU_K02 understands necessity of systematic and individual work on the material of the course.

PROGRAMME CONTENT		
Form of classes - lecture		**Number of hours**
Lec1	A reminder of information concerning first order partial differential equations. Methods of characteristics, weak solutions and shock waves.	4
Lec2	Second order partial differential equations and their classification. Physical motivations.	2
Lec3	Parabolic equations and their applications (heat, diffusion). Initial-boundary problems, method of separation of variables, Fourier transform, fundamental solution, maximum principle.	8
Lec4	Hyperbolic equations and their applications (vibration of strings, membranes and beams; acoustical, mechanical and electromagnetic waves). D'Alembert's solution, initial-boundary problems, method of separation of variables, Kirchhoff's solution, Huygens' principle.	8
Lec5	Elliptic equations and their applications (stationary temperature distribution, gravitational and electrostatic potential). Boundary value problems, eigenfunctions, Poisson's equation, Green's function.	6
Lec6	The calculus of variations and its applications. Euler-Lagrange equation, Lagrangian mechanics, geodesic equation, minimal surface equation.	2
	Total hours	**30**

Form of classes - Class		**Number of hours**
Cl1	Solving of problems for differential equations and their applications.	**30**
	Total hours	**30**

TEACHING TOOLS USED
1. Lecture – traditional method 2. Tutorial class 3. Consultations 4. Student’s personal work – preparation for the laboratory

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_U02 PEU_K01	Oral presentations, tests, written reports.
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] S.J.Farlow, Partial Differential Equations for Scientists and Engineers, Dover Publications, 1993. [2] R.Haberman, Applied Partial Differential Equations with Fourier Series and Boundary Value Problems, Pearson, 2012. [3] A. N. Tichonow, A. A. Samarski, Równania fizyki matematycznej, PWN 1963. **SECONDARY LITERATURE:** [1] J. Ockendon, S. Howison, A. Lacey & A. Movchan, Applied Partial Differential Equations, Oxford University Press, Oxford 1999. [2] L. C. Evans, Równania różniczkowe cząstkowe, PWN 2002.
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FACULTY OF PURE AND APPLIED MATHEMATICS
SUBJECT CARD
Name of subject in Polish METODY PERTURBACYJNE
Name of subject in English Perturbation Methods
Main field of study (if applicable): APPLIED MATHEMATICS
Specialization (if applicable): Mathematics for Industry and Commerce
Level and form of studies: ~~1st/~~ 2nd* level, full-time ~~/ part-time*~~
Kind of subject: ~~obligatory /~~ optional ~~/ university-wide~~*
Subject code
Group of courses YES / ~~NO~~*

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30		30		
Number of hours of total student workload (CNPS)	90		60		
Form of crediting	crediting with grade				
For group of courses mark (X) final course	X				
Number of ECTS points	3		2		
including number of ECTS points for practical classes (P)	2		2		
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5		1,5		

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES
1. The student knows and he is able to use the classic concepts and theorems of mathematical analysis
2. Second He knows and is able to apply basic concepts and methods in the field of differential equations

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SUBJECT OBJECTIVES
C1 Understanding the basic concepts and mastering the basic techniques used in the methods of perturbation

SUBJECT EDUCATIONAL EFFECTS
relating to knowledge:
PEU_W01 has in-depth knowledge of the methods of perturbation
PEU_W02 know the numerical methods used to find approximate solutions mathematical problems (for example, differential equations) pose in the field of applied domain

relating to skills:

PEU_U01 can construct mathematical models used in concrete advanced applications of mathematics relating to social competences: PEU_K01 can benefit from the scientific literature in English, including reaching the source materials and make them review

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Examples of problems leading to perturbation method	2
Lec 2	Regular perturbation method	2
Lec 3	Poincare-Lindstedt method	2
Lec 4	Asymptotes	2
Lec 5	Unreliability of the regular perturbation method	2
Lec 6	Singular perturbation method	2
Lec 7	The inner and outer approximations	2
Lec 8	Analysis of shoreline layer	2
Lec 9	Inner approximation and scaling	2
Lec 10	Combining internal and external approximation	2
Lec 11	Uniform approximation	2
Lec 12	Examples of uniform approximation	2
Lec 13	Phenomena associated with the film edge	2
Lec 14	Partial differential equations and perturbation methods	2
Lec 15	Algebraic equations and perturbation methods	2
	Total hours	30

Laboratory		**Number of hours**
Lab 1	Solving problems illustrating a lecture given theory using MATLAB	30
	Total hours	30

TEACHING TOOLS USED
N1. Lecture - traditional method N2. Computer laboratory N3. Individual consultation N4. Student's own work - to prepare for the lab

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W1 PEU_W2	test
F2	PEU_U1 PEU-K1	verbal responses, short tests, tests, reports
C=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
<u>**PRIMARY LITERATURE:**</u> [1] E. J. Hinch, Perturbation Methods. [2] J. David Logan, Applied Mathematics. <u>**SECONDARY LITERATURE:**</u> [1] C.C.Lin, L.A.Segel, Mathematics Applied to Deterministic Problems in the Natural Sciencec, SIAM 1988
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Zał. nr 5 do ZW 16/2020

FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: TEORIA KOLEJEK I SIECI KOMUNIKACYJNE
Name of subject in English: Queues and Communication Networks
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): MODELLING, SIMULATION, OPTIMIZATION
Profile: academic / practical*
Level and form of studies: 2nd level/ full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1,5	1,5			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student has an elementary knowledge of probability theory.

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SUBJECT OBJECTIVES

C1 Learning and mastery of key concepts and methods in the field of queueing theory and communication networks

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the most important theorems and hypotheses of queuing theory
PEU_W02 knows the basics of stochastic modeling of stochastic networks with applications to biology, physics, economics etc.
relating to skills:
PEU_U01 can construct queuing models used in various applications
relating to social competences:
PEU_K01 can by himself/herself search for information in the literature, even in foreign languages

PROGRAMME CONTENT

Lecture		Number of hours
Lec 1	Basic concepts from Markov processes theory	2
Lec 2	An outline of the theory of point processes	2
Lec 3	Steady state analysis of Markovian queues	4
Lec 4	Erlang Loss System	2
Lec 5	Open Jackson network and Gordon-Newel network	6
Lec 6	Multi-class Queue	4
Lec 7	Multiserver queus and various queue disciplines	4
Lec 8	Queues with feedback and loss systems	4
Lec 9	Transient analysis of Markovian queues	2
	Total hours	**30**

Classes		Number of hours
Cl 1	Illustration of all models.. Analytical and computer methods. Examples of queuing models.	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture problem - traditional method. N2. Problem and counting exercises. N3. Consultations. N4. Student's self work - preparation for exercises.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming (during semester), P – concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_W01 PEU_W02 PEU_K01	exam
F2	PEU_U01 PEU_K01	oral responses, tests, small tests
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE: [1] Asmussen, S. (2003) Applied Probability and Queues, Springer. **SECONDARY LITERATURE:** [1] Cohen, J.W. (1969) The Single Server Queue North, Holland. [2] Takacs, L. (1962) Introduction to the Theory of Queues Oxford University Press.
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FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Rezerwy w ubezpieczeniach życiowych i majątkowych
Name of subject in English: Reserves in life and non-life insurance
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Financial and Actuarial Mathematics
Profile: academic / practical*
Level and form of studies: 2nd level / full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30	30			
Number of hours of total student workload (CNPS)	90	60			
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3	2			
including number of ECTS points for practical classes (P)	2	2			
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1.5	1.5			

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic concepts of the probability theory
2. Student knows and can apply basic concepts of actuarial mathematics including life and non-life insurance.

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SUBJECT OBJECTIVES

C1 Study of the classical concepts and acquisition of the knowledge of reserving in life and non-life insurance

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:
PEU_W01 knows the most important concepts of reserving in life and non-life insurance mathematics
PEU_W02 knows principles of stochastic modeling in life and non-life insurance mathematics

relating to skills:

PEU_U01 can construct mathematical models used in reserving in life and non-life insurance mathematics

relating to social competences:
PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Introduction to the course, survey over provision types.	2
Lec 2	Net reserves in life insurance.	4
Lec 3	Decomposition of the loss random variable (Hattendorff's theorem).	2
Lec 4	Technical gain.	2
Lec 5	Gross reserves in life insurance, Zillmer's reserve	2
Lec 6	Multiple decrement model: net premiums and reserves	4
Lec 7	Multiple life insurance: net premiums and reserves	6
Lec 8	Provisions in non-life insurance, including loss data triangles, chain-ladder method, IBNR, premium reserve	4
Lec 9	Solvency II - technical provisions, best estimate, risk margin, technical provisions for accounting purposes	4
	Total hours	**30**

Classes		**Number of hours**
Cl 1	Solving of problems illustrating theory given in the lectures, solving of problems from actuarial exams	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method. N2. Problem-solving classes. N3. Consultations. N4. Student's self-work – preparation for the classes.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02	Exam

	PEU_K01	
F2	PEU_U01 PEU_K01	Oral presentations, tests
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE
PRIMARY LITERATURE: [1] N. L. Bowers at al „Actuarial Mathematics", The Society of Actuaries, Itasca, Illinois 1997. [2] H. U. Gerber „Life insurance mathematics", Springer-Verlag, Berlin 1997. [3] M. J. Goovaerts et al. „Effective Actuarial Methods"; North Holland, 1990. [4] R. Kaas et al. „Modern Actuarial Risk Theory"; Kluwer Academic Publishers, 2001.
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FACULTY OF PURE AND APPLIED MATHEMATICS

SUBJECT CARD

Name of subject in Polish: Zarządzanie ryzykiem w ubezpieczeniach
Name of subject in English Risk management in insurance
Main field of study (if applicable): Applied Mathematics
Specialization (if applicable): Financial and Actuarial Mathematics
Profile: academic / practical*
Level and form of studies: 2nd level / full-time /
Kind of subject: optional
Subject code
Group of courses YES

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU)	30			30	
Number of hours of total student workload (CNPS)	90			60	
Form of crediting	Examination				
For group of courses mark (X) final course	X				
Number of ECTS points	3			2	
including number of ECTS points for practical classes (P)	2			2	
including number of ECTS points corresponding to classes that require direct participation of lecturers and other academics (BU)	1.5			1.5	

*delete as not necessary

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Student knows and can apply basic concepts of the probability theory
2. Student knows and can apply basic concepts of actuarial mathematics including life and non-life insurance.
3. Student knows and can apply basic concepts of reserving in life and non-life insurance mathematics

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SUBJECT OBJECTIVES

C1 Study of the classical concepts and acquisition of the knowledge of risk management in life and non-life insurance

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:

PEU_W01 knows the most important concepts of risk management in life and non-life insurance mathematics PEU_W02 knows principles of stochastic modeling in risk management relating to skills: PEU_U01 can construct mathematical models and apply methods used in risk management in life and non-life insurance mathematics relating to social competences: PEU_K01 can, without assistance, search for necessary information in the literature, also in foreign languages

PROGRAMME CONTENT		
Lecture		**Number of hours**
Lec 1	Risk management in insurance, actuarial function, risk management function	2
Lec 2	Capital management, risk appetite, risk measures (including RAROC, RORAC)	2
Lec 3	Solvency II: capital requirements, standard formula, internal models, risk categories	6
Lec 4	Profitability and risk exposure tests, monitoring of actuarial assumptions or parameters	4
Lec 5	Risk exposure reduction methods, methods and instruments of risk transfer including alternative risk transfers (ART)	4
Lec 6	Proportional and non-proportional reinsurance as method of risk exposure reduction	4
Lec 7	Actuarial pricing in life and non-life insurance, risk factors.	2
Lec 8	Application of derivatives in insurance	3
Lec 9	Pricing of catastrophe bonds.	3
	Total hours	**30**

Project		**Number of hours**
Proj 1	Preparation and presentations of projects illustrating theory given in the lectures.	30
	Total hours	**30**

TEACHING TOOLS USED
N1. Lecture – traditional method and presentations N2. Student partial project presentation and final presentation N3. Consultations N4. Student’s self-work – work on the project development

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT

Evaluation (F – forming during semester), P – concluding (at semester end)	Learning outcomes code	Way of evaluating learning outcomes achievement
F1	PEU_W01 PEU_W02 PEU_K01	Exam
F2	PEU_U01 PEU_K01	Partial project presentations, final project presentation
P=0.5*F1+0.5*F2		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] N. L. Bowers and others, „Actuarial mathematics", The Society of Actuaries, Itasca, Illinois, 1997.
[2] H. U. Gerber, „Life insurance mathematics", Springer-Verlag, Berlin, 1997.
[3] C. D. Daykin and others, „Practical risk theory for actuaries", Chapman & Hall, London, 1996.
[4] R. Kaas, M. Gooveaerts, J. Dhaene, M. Denuit „Modern actuarial Risk Theory", Springer-Verlag, Berlin Heidelberg, 2008.
[5] P.M. Booth, R. G. Chadburn, S. Haberman et al. „Modern actuarial theory and practice" 2nd ed.; Chapman & Hall, 2005
[6] M. V. Wüthrich, M. Merz,"Financial Modeling, Actuarial Valuation and Solvency in Insurance", Springer-Verlag Berlin Heidelberg, 2013.
[7] DIRECTIVE 2009/138/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II)

SECONDARY LITERATURE:

[1] L. Hölscher, P. Harding, G. M. Becker, „ Financing the Embedded Value of Life Insurance Portfolios", HfB – Working Paper Series, 2005.

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