Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Approximation Theory		
Lecturer (for lectures)	Džunić S. Jovana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Train students to design and analyze numerical techniques of approximation practice. Lay theoretical foundation for the wider field of advanced approximating techniques. Engage and motivate students with exemplar applications. Capacitate students to apply and experiment with modern technical computing software. Build knowledge and develop skills for independent scientific research.		
Course outcomes	Solve mathematical problems using computational methods. Design and apply efficient numerical tools. Understand capabilities and limitations of numerical algorithms and algebra systems. Capability to search, analyze and synthesize data and information, with the use of adequate software.		
Course outline			
Theoretical teaching	Polynomials in scientific computing and industrial applications. Representations of polynomials. Univariate polynomials: vector space, algebraic and analytic properties. Root-finding techniques. Interpolation and data fitting. Rational functions. Iteration of rational functions. Rational interpolation and Data fitting. Polynomials in several variables. Numerical factorization. Applications with the use of software.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	H. Stetter, Numerical polynomial algebra, SIAM, 2004		
2	D. Bini, V. Pan, Polynomial and matrix computations, Springer, 1994		
3	N. Trefethen, Approximation theory and approximation practice, SIAM, 2013		
4	A. Beardon, Iteration of rational functions, Springer, 1991		
5	V. Praslov, Polynomials, Springer, 2004		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	40
Exercises		**Oral exam**	
Colloquia			
Projects	60		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Numerical Linear Algebra		
Lecturer (for lectures)		Džunić S. Jovana		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	The goal of this course is to enable students to design and analyze numerical techniques of numerical linear algebra. To prepare them for independent research and responsible communication of results. To establish theoretical foundation for error and stability analysis and perturbation theory. Capacitate students to apply and experiment with modern technical computing software.			
Course outcomes	Design and apply efficient numerical tools. Understand capabilities and limitations of computing algorithms and algebra systems. Capability to search, analyze and synthesize data and information, with the use of adequate software.□			
Course outline				
Theoretical teaching	Introduction to MATLAB. Introduction to LaTex. Errors. Vector and matrix norm. Perturbation, conditioning, stability. Matrix transformations and applications. Dimension reduction. Least squares problems.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	C. Meyer, Matrix analysis and applied linear algebra, SIAM, 2000			
2	A. Bjork, Numerical methods in Matrix computations, Springer, 2015			
3	N. Higham, Accuracy and stability of numerical algorithms, SIAM, 1996			
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	40
Colloquia			
Projects	60		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Stastistics		
Lecturer (for lectures)	Milošević M. Dušan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Mastering basic knowledge of statistics and work in the SPSS package.		
Course outcomes	Acquiring theoretical knowledge and practical skills.		
Course outline			
Theoretical teaching	Statistical methodology. Descriptive analysis. Arranging and displaying data. Descriptive measures. Measures of central tendency and dispersion. Distribution of discrete and continuous random variables. Sample and sample statistics. Statistical testing methods. Hypothesis testing. T-test, Analysis of variance with one and two factors. Pearson's chi-squared test. Simple linear regression and correlation. Multiple regression and correlation. Factor analysis. Taxonomic analysis. Discrimination analysis. Non-parametric methods. Index numbers, Analysis of time series. Working in the SPSS program package.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	H. J. Seltman, Experimental Design and Analysis,Online at: http://www. stat. cmu. edu/, hseltman/309/Book/Book. pdf, 2018.		
2	A. Abebe, J. Daniels, J. W. McKean, J. A. Kapenga, Statistics and Data Analysis, Statistical Computation Lab (SCL) Western Michigan University, Kalamazoo, MI.		
3	M. Žižić, M. Lovrić, D. Pavličić, Methods of statistical analysis (in Serbian), Faculty of Economics, University of Belgrade, 2007,		
4	J. Pallant, SPSS Survival Manual, sixth edition, Open University Press 2016.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, computer exercises, consultation, preparation of seminar work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	10	**Written exam**	
Exercises		**Oral exam**	30
Colloquia	30		
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Numerical Mathematics		
Lecturer (for lectures)	Marjanović M. Zvezdan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering theoretical and practical knowledge in some areas of numerical mathematics (error propagation and ill-conditioned systems, iterative processes, solving operator equations and their concretization, quadrature processes, approximatly solving ordinary and partial differential equations) using the Mathematica programming package.		
Course outcomes	Theoretical and practical knowledge; Mastering use of Mathematica software package.		
Course outline			
Theoretical teaching	Arithmetic of finite length and numerical processes. General theory of iterative processes. Application to operator equations. Nonlinear equations and systems. Quadrature processes and convergence. Cauchy's problems and contour problems for ordinary dferential equations. Grid method for partial diferential equations. Symbolic computation and algorithms. Implementation of algorithms using the Mathematica package.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G. V. Milovanović: Numerical analysis I (in Serbian). Scientific Book, Belgrade 1991.		
2	G. V. Milovanović: Numerical analysis II (in Serbian). Scientific Book, Belgrade 1991.		
3	G. V. Milovanović: Numerical analysis III (in Serbian). Scientific Book, Belgrade 1991.		
4	B.Jovanović: Numerical methods for solving partial differential equations (in Serbian). Mathematical Institute, Belgrade 1989.		
5	G.V. Milovanovic, M.A. Kovacevic, M.M. Spalevic: Numerical Mathematics – A Collection of Solved Problems (in Serbian), Faculty of Electronic Engineering, Niš, 2003.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Computer exercises. Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Discrete structures and combinatorics		
Lecturer (for lectures)	Milovanović Ž. Igor, Matejić M. Marjan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring scientific, theoretical and practical knowledge of enumerative combinatorics, algebraic combinatorics and spectral graph theory		
Course outcomes	Students should be qualified for further independent scientific and research work in solving various combinatorial problems.		
Course outline			
Theoretical teaching	Special number sequences. Stirling numers. Bell numbers. Catalan numbers. Euler numbers. Bernouli numbers. Applications in combinatorial mathematics. Extremal problems. Combinatorial block schemes. Special matrices: Binary, Hadamard, Stohastics, Permutation matrices. Combinatorial distribution and counting problems. Spectral matrices and graph theory. Graph invariants. Energy of matrices and graphs. Directed graphs. Mapping of directed coordinated graphs on plane and line.		
Practical teaching (exercises, OFE, study and research	Individual research study		
Textbooks/references			
1	A. Anderson, Discrete Mathematics with Combinatorics, Second Edition, Prentice Hall, 2003		
2	F.R.K.Chung, Spectral graph theory, Providence, 1991.		
3	I.Gutman, B.Furtula, K.Ch. Das, E. Milovanović, I. Milovanović, Bounds in chemical graph theory - Mainstreams, MCM, Kragujevac, 2017.		
4	I.Gutman, X.Li (eds.), Energies of graphs - Theory and applications, MCM, Kragujevac, 2016.		
5	релевантни научни чланци		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Consultations, disscussion, individual research.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Special functions		
Lecturer (for lectures)	Marinković D. Slađana, Rančić Z. Lidija		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Gaining comptences within the framework of the theory of special functions and its application in professional and scientific research in mathematical or engineering disciplines.		
Course outcomes	Solid theoretical knowledge of different classes of special functions and the ability to apply them in research in mathematics or related fields. Students' ability to critically identify and evaluate contemporary literature as a prerequisite for independent research work.		
Course outline			
Theoretical teaching	Hypergeometric functions: definition, recursive and transformation formulas, differential equation. Functions defined by integrals: Gamma function, Beta function, Bessel functions. Orthogonality in Hilbert space. Orthogonal polynomials: zeros, differential equation, three-term recurrence relation, generating function, hypergeometric representation. Construction of orthogonal polynomials. Classical orthogonal polynomials. Orthogonal polynomials with non-classical weights. Elements of fractional calculus. Fractional integral. Fractional derivative of Riemann-Liouville and Caputo type. Mittag-Leffler function.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Gradimir V. Milovanović, Numerical Analysis I, Naučna knjiga, Belgrade, 1985. (Serbian)		
2	G.E. Andrews, R. Askey, R. Roy, Special Functions, Encyclopedia of Mathematics and its Aplications, Cambridge University Press, Cambridge, 1999.		
3	Dragoslav S. Mitrinović, Introduction to special functions, Gradjevinska knjiga, Belgrade, 1986.(Serbian)		
4	I. Podlubni, Fractional Differential Equations, volume 198 of Mathematics in Science and engineering, Academic Press, San Diego, 1999.		
5			

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	lectures, mentoring work			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Mathematical Methods of Optimization		
Lecturer (for lectures)	Marinković D. Slađana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Gaining mathematical knowledge of optimization and different optimization methods. Developing skills of mathematical modelling of real problems of practice or scientific research, as well as solving them.		
Course outcomes	Students' competence to identify the optimization problems of practice or scientific research, develop mathematical models, choose the appropriate methods for their solving and the application of methods. Competence to critically identify and evaluate contemporary literature as a prerequisite for independent research work.		
Course outline			
Theoretical teaching	Elements of convex analysis. Convex sets and convex functions. Subgradients and generalization of convexity. Optimality and regularity conditions. Lagrange function and duality. Linear programming and simplex method. Nonlinear programming. Quadratic programming. Algorithms and convergence. Unconstrained optimization. Constrained optimization. Interior point method. Multiobjective optimization. Elements of calculus of variations. Variational methods.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G.V. Milovanović, P.S. Stanimirović: Symbolic Implementation of Nonlinear Optimization, Faculty of Electronic Engineering, Niš, 2002 (Serbian).		
2	S. Boyd, L. Vandenberghe, Convex optimization, Cambrige University Press, 2009.		
3	Z. Michalewicz, D.B. Fogel, How to Solve it: Modern Heuristics, Springer-Verlag, Berlin Heidelberg, 2000.		
4	K. W. Cassel, Variational Methods with Applications in Science and Engineering, University Press, Cambridge, 2013.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, mentoring work			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Analysis of Numerical Algorithms		
Lecturer (for lectures)	Marjanović M. Zvezdan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Acquiring knowledge in numerical mathematics.		
Course outcomes	Students' ability to apply acquired knowledge in the profession.		
Course outline			
Theoretical teaching	Problems of linear algebra. Direct and iterative methods for solving a system of linear equations, matrix inversion , and the finding matrix eigenvalues. Ill-conditioned systems. Nonlinear equations and systems. Newton and other methods. Method of Newton - Kantorovich. Algebraic equations. Bernoulli's method. Simultaneous method. Gauss - Seidel's approach. Approximation of functions. Interpolation. Problem of the best approximations. Differentiation and integration. Newton - Cotes and Gaussian quadrature formulas. Acceleration methods: convergence of sequences and series, matrix multiplication. Aitken method. Euler - Abel transformation. Fast Fourier Transformation (FFT).		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G. V. Milovanović: Numerical analysis I (in Serbian). Scientific Book, Belgrade 1991.		
2	G. V. Milovanović: Numerical analysis II (in Serbian) . Scientific Book, Belgrade 1991.		
3	G. V. Milovanović: Numerical analysis III (in Serbian). Scientific Book, Belgrade 1991.		
4	G.V. Milovanović, M.A. Kovačević, M.M. Spalević: Numerical Mathematics – A Collection of Solved Problems (in Serbian), Faculty of Electronic Engineering, Niš, 2003.		
5	Dobrilo Dj.Tošić: Introduction to numerical analysis with a collection of tasks and problems (in Serbian). Academic mind, Belgrade, 2004.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations on specific topics, seminars and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Spectral graph theory		
Lecturer (for lectures)	Matejić M. Marjan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The main aim of the course is the acquisition of knowledge and techniques of the spectral graph theory.		
Course outcomes	The student has acquired theoretical knowledge necessary for understanding the problems related to the spectral graph theory and its application in other fields of mathematics, as well as in natural and technical sciences. The student mastered the skills and methods of research in this field.		
Course outline			
Theoretical teaching	Topological indices of the graph based on the degrees of vertices and edges (Zagreb indices, Randić indices, geometric-arithmetic topological index, ABC topological index, ISI, SDD, ...). Basic characteristics of topological indices, bounds, values on concrete graphs. Matrices associated with the graph (adjacency matrix, adjacency matrix by edges, incident matrix, Laplacian matrix, normalized Laplacian matrix, Randic matrix, signless Laplacian matrix, ...). Graph spectrums and basic properties. Energy of matrices and graphs. Kirchhoff indices. Operations with graphs and spectra. Regular graphs. Measures of irregularity of graphs.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. M. Cvetković, M. Doob, H. Sachs, Spectra of graphs, Johann Ambrosius Barth, Heidelberg - Leipzig, 1995.		
2	F. R. K. Chung, Spectral graph theory, American Mathematical Society, 1997.		
3	A. E. Brouwer, W. H. Haemers, Spectra of graphs, Springer, 2012.		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, student seminars, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Highly Efficient Iterative Methods		
Lecturer (for lectures)	Rančić Z. Lidija		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Students are trained to contribute to the development of new iterative methods and their application.		
Course outcomes	Students are familiar with the construction elements and the analysis of the convergence of iterative methods for solving some classes of nonlinear equations and the linear equations system. They are trained to apply acquired knowledge through self-study and possibly writing scientific paper in this topic.		
Course outline			
Theoretical teaching	Basic characteristics of iterative methods. Convergence analysis, order of convergence, R-order of convergence. Initial values problem and stability of methods. High precision iterative methods for determining the zeroes of the analytic function and the zeroes of polynomial.Iterative methods for determining the solution of the linear equations system (the Krilov space, Arnoldi iteration, GMRS method).Application of mathematical software tools in realization of the mentioned methods.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Miodrag Petković, Lidija Rančić, Dušan Milošević, Numerical solving of nonlinear equations, Faculty of Electronic Engineering, University of Niš, 2009.(Serbian)		
2	Miodrag Petković, Iterative Methods for Simultaneous Inclusion of Polynomial Zeros, Springer-Verlag-Berlin-Heidelberg-New York,1989, Reprinted 2008.		
3	Yousef Saad, Iterative Methods for Sparse Linear Systems, SIAM, Philadelphia,2003		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, tutorials			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Simulation of Industrial Systems		
Lecturer (for lectures)	Milojković T. Marko, Perić Lj. Staniša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Modern trends of industrial development impose the growing need for simulation, especially where operations and tests on systems themselves are impractical, unprofitable or dangerous. Quality performed simulation requires both good mathematical basis and knowledge of industrial systems and related software.		
Course outcomes	Acquiring knowledge about the mathematical basis of quality simulation and obtaining adequate simulational models to solve practical problems in various areas of industry. Knowledge of appropriate software for the simulation as well as the current trends in the simulation of industrial systems.		
Course outline			
Theoretical teaching	The concept of simulation and methods. Design of simulation models. Simulation tools. The mathematical foundation of digital simulation. Numerical methods implemented in simulation tools. Simulation of systems with distributed parameters. Simulation of systems with discontinuities. Errors in the simulation and methods for overcoming them. The application of simulation in the identification, design and optimization of automatic control systems. Real-time simulation, hardware and software aspects, algorithms for numerical integration. Simulation of industrial systems. Simulation of complex systems. Modern trends in the simulation of industrial systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. Antić, B Danković, "Modelling and simulation of dynamical systems", Faculty of Electronic Engineering, Niš, 2001. (in Serbian)		
2	M. Milojković, D. Antić, S. Nikoli', "Practical handbook on modelling and simulation of dynamical systems", Faculty of Electronic Engineering, Niš, 2018. (in Serbian)		
3	H. Klee, “Simulation of Dynamic Systems with Matlab and Simulink”, CRC Press, 2007.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Teaching methods (classical - lectures or mentor - consultations) will be adapted acording to the number of students. By using scientific journals and other literature, the student deepens the material from lectures, and through the consultations and study research with the teacher student is trained to write his own scientific work. The student is required to do the project alone.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Mathematical Models in Industry		
Lecturer (for lectures)	Antić S. Dragan, Milojković T. Marko		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Training students to meet the increasing needs of the modern industry for abstract models and predictions both during research and in the production process itself.		
Course outcomes	Gaining knowledge of the mathematical models in the industry, their obtaining and applications as well as possibilities for the use of sophisticated mathematical methods to solve practical problems of the modeling in the modern industry.		
Course outline			
Theoretical teaching	Models of dynamical systems. The classification of the models. Abstract models. Principles of mathematical modeling. Types of mathematical models. Examples of mathematical models. The mathematical modeling of technical systems (mechanical, hydraulic, thermal, chemical and technological). Simplification of mathematical models. Validation and verification of the model. Mathematical modeling of disturbance. Modelling of industrial systems. Modeling of complex systems. Current trends in modeling of industrial systems. Modeling using orthogonal functions. Applications of genetic algorithms, fuzzy logic and neural network in the mathematical modeling in the industry. Commercial software for the modeling of industrial systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. Antić, B Danković, "Modelling and simulation of dynamical systems", Faculty of Electronic Engineering, Niš, 2001. (in Serbian)		
2	M. Milojkovic, D. Antić, S. Nikolic, "Practical handbook on modelling and simulation of dynamical systems", Faculty of Electronic Engineering, Niš, 2018. (in Serbian)		
3	C. Close, D. Frederick, J. Newell, “Modeling and Analysis of Dynamic Systems”, John Wiley & Sons, 2002.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Teaching methods (classical - lectures or mentor - consultations) will be adapted acording to the number of students. By using scientific journals and other literature, the student deepens the material from lectures, and through the consultations and study research with the teacher student should be trained to write his own scientific work.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Mathematical Foundations of Statistical Learning and Applications		
Lecturer (for lectures)		Perić H. Zoran, Milošević M. Dušan		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Introduction to the mathematical basics of statistics and statistical learning. Enabling students to apply the acquired knowledge on the concrete tasks.			
Course outcomes	Acquired fundamentals of statistical learning and ability to practically use the acquired knowledge in the signal and data processing.			
Course outline				
Theoretical teaching	Point estimates, confidence intervals. Nonparametric methods for distribution hypothesis testing. Maximal likelihood method. Linear regression, dependence between two random variables, regression line, dependence between random and control variable. Nonlinear regression, piecewise linear regression, logistic regression. Time series analysis, linear and nonlinear prediction. AR processes, MA processes and ARMA processes. Training alghorithms based on statiatical learning. Algorithms			
Practical teaching (exercises, OFE, study and research	Lectures. Consultations. Work on project.			
Textbooks/references				
1	G. James, D. Witten, T. Hastie, R. Tibshirani, An Introduction to Statistical Learning with Applications in R, Springer, 2017.			
2	T. Hastie, R. Tibshirani, J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, 2nd Edition, Springer, 2009.			
3	Milan Merkle, Probability and Statistics (in Serbian), IV edition, Academical thought, 2016.			
4	D. Milosevic, L. Rancic, M. Petkovic, Mathematics IV (in Serbian), Faculty of Elcetronics Engineering, 2015.			
5	V. N. Vapnik, Statistical Learning Theory, Wiley-Interscience, 1998.			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations. Work on project.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Digital Systems		
Lecturer (for lectures)		Đorđević Lj. Goran		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	The goal of the course is to expand and upgrade the knowledge gained in the field of digital system design and the adoption of new design methodologies and techniques needed for the design, analysis and implementation of complex digital high performance systems.			
Course outcomes	The learning outcome of the course is students' ability to use modern methods and design techniques, with the support of appropriate software tools in order to: a) design, analyze and realize digital systems of different levels of complexity, and b) explore alternative solutions in order to find the optimal compromise between hardware complexity, performance and consumption.			
Course outline				
Theoretical teaching	Characteristics of modern digital systems. Advanced technologies for realization of combinational and sequential digital circuits. Low-voltage and low power consumption digital systems. Asynchronous digital systems. Methodologies for designing complex digital systems at different levels of abstraction: RTL design and high level synthesis. Synthesis of the data path and control unit. Techniques for improving the performance of digital systems: pipeline and parallel architectures. Principles of hardware realization of arithmetic functions and DSP algorithms. Architecture of programmable digital circuits. Fault tolerant digital systems.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	D. Gajski, Principles of Digital Design, Prentice-Hall, Inc. Upper Saddle River, NJ, 1997.			
2	N.H E. Weste, D. M. Harris, CMOS VLSI Design - A Circuits and Systems Perspective, 4th Edition, Addison Wesley, 2010			
3	E.C. Ifeachor, B. W. Jervis, Digital Signal Processing: A practical approach, Pearson Education, PHI/ 2002			
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, seminars, assignments, and class discussions. Independent and team work of students in solving research-oriented tasks.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Power Electronics		
Lecturer (for lectures)		Mančić D. Dragan		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Expanding and upgrading the fundamental knowledge acquired in the field of power electronics and guidance towards the adoption of new techniques required by concrete and specific applications which are subject of interest to students.			
Course outcomes	Students gain the necessary theoretical and practical knowledge to meet any specific request in development, modeling, performance assessment, optimization, realisation, control, practical application and verification of the various devices of power electronics with medium level of complexity, primarily of the various power electronic converters.			
Course outline				
Theoretical teaching	Types of semiconductor power electronic switches. AC/DC converters. Rectifiers in switching mode of operation. Rectifiers for power factor corrector. Multi-quadrant work. DC/DC converters. DC/AC converters. Soft starters, frequency converters. Converters for medium voltage levels. Methods of control. Direct AC/AC converters. Sizing the components of inverter. Influence of converters on the power grid and electrical consumers. Utilization of special purpose softwares in the operation analysis of inverters.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	N.Mohan, T.M.Undeland, W.P.Robbins, "Power electronics: Converters, Applications, and Design", John Wiley & Sons., New York, 2007.			
2	M.H.Rashid, "Power electronics, Circuits, Devices and Applications", Pearson Education, Inc., New Jersey, 2013.			
3	M.H.Rashid, "Power Electronics Handbook", Elsevier Science, 2017.			
4	P.C.Sen, “Principles of Electric Machines and Power Electronics”, John Wiley & Sons Inc., New Jersey, 2013.			
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching is held in lectures while simultaneously mentoring students. Individual and team work of students takes place during their practical and scientific and research work on the defined projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Computer Architecture		
Lecturer (for lectures)	Nikolić R. Tatjana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	This course will focus on the crucial techniques for hardware and software design of high performance modern computer systems with consideration of the newest architectural innovations.		
Course outcomes	Students acquire knowledge about advanced computer architectures including modern architectural techniques of newer CPU generations, memory and input/output subsystems, as well as programming techniques. During this course the student learns how to design high performance computer systems and evaluate their performances.		
Course outline			
Theoretical teaching	Performance evaluation of computer systems: metrics, average performance, errors in estimation, tools and techniques for the estimation, benchmark programs. Overview of advanced computer architecture: pipeline, superscalar, VLIW, DSP and multimedia processors, multicore and multithread architectures. Instruction level, machine level and thread level parallelism. Chip multiprocessors. Design challenges and constraints. Memory system. Memory hierarchy. Register file. Scratch pad memory. Main memory organization. Cache hierarchy. Coherence, synchronization, memory consistency. Memory implementation concepts for mass storage. Virtual memory and paging. Input-output organization and interfaces. Programming input-output. Buses. Context switching and interruptions. Networks on chip. Topologies. Routing and switching techniques. High speed data transfer. Specific purpose processors. Application specific integrated processors. High performance energy efficient processors. Programming techniques. Simulators of computer systems. Estimation of power consumption and chip area.		
Practical teaching (exercises, OFE, study and research	Preparation of seminar papers in the field of cache memory, input-output subsystems, multiprocessor system-on-chip.		
Textbooks/references			
1	J. L. Hennessy, D. A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann, 2012.		
2	D. A. Patterson, J. L. Hennessy, Computer Organization and Design, The hardware/software interface, Elsevier Inc., 2014.		
3	Michel Dubois, Murali Annavaram, Per Stenstrom, Parallel Computer Organization and Design, Cambridge University Press, 2012.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching is held in a form of lectures and mentoring work with studets. Independent and team work of students during solving tasks within research projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Optimization and Design of Analog Circuits		
Lecturer (for lectures)		Andrejević-Stošović V. Miona		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Extending knowledge from the analog electronics, analog integrated circuits and design of analog integrated circuits, studied in courses in bachelor and master studies.			
Course outcomes	Acquiring the knowledge required for the doctoral dissertation.			
Course outline				
Theoretical teaching	Wideband transistor models. Operational amplifiers in bipolar, CMOS and NMOS technology and their basic cells. Transconductance, quarter-quadrant analog multipliers and PWAM. Analog (PLL) and digital (DLL) architecture, components and key parameters. SC filters.			
Practical teaching (exercises, OFE, study and research	Acquired theoretical knowledge students need to apply by optimizing and designing analog integrated circuits using the professional software package for design of integrated circuits -Cadence.			
Textbooks/references				
1	Baker R. Jacob, CMOS: circuit design, layout, and simulation, Fourth Edition. John Wiley & Sons, 2019. ISBN 9781119481515.			
2	B. Razavi, "Design of Analog CMOS Integrated Circuits", McGraw-Hill Internationsl Edition, ISBN: 0-07-118815-0, 2001.			
3	Hans Camenzind, Designing Analog Chip¸ Copyright 2004, 2005.			
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, practice exercises, research.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Signal Processing		
Lecturer (for lectures)	Nikolić V. Saša, Stančić Z. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Presentation of advanced topics in digital signal processing. Presentation of state of the art algorithms for digital filter design.		
Course outcomes	Modern approaches for design and implementation of digital filters.		
Course outline			
Theoretical teaching	Parametric signal modeling. Spectral estimation. Multirate processing of digital signals. Efficient Fourier transform and convolution algorithms. Two dimensional signal processing. Advanced topics in filter design.		
Practical teaching (exercises, OFE, study and research	Practical implementation of algorithms for digital filter design in one and two dimension.		
Textbooks/references			
1	J. Lim, A. Oppenhaim: Advanced topics in signal processing, Prentice Hall.		
2	Y. Hussain, A. Sadik, P. Oshea: Digital signal processing, Springer 2011.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations, seminars, projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electronic Circuits and Systems Design		
Lecturer (for lectures)	Petković M. Predrag		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Adopting and systematizing knowledge about methods and styles for designing electronic circuits and systems. Adopting advanced knowledge related to tools for electronic circuits and systems design in nano CMOS technologies.		
Course outcomes	Acquiring competencies for optimal choice of design methods depending on specific requirements. A detailed insight into the automated design and data flow in design tools. Upon completion of this course, students will have at least one complete projected electronic circuit (from functional description to preparation of data necessary for production) using the Cadence (and/or) Synopsis design tools.		
Course outline			
Theoretical teaching	Electronic circuits and systems design styles. Domains of project description. Design flow phases. Automation of design. Data formats in design tools. Design based on predesigned structures, semi-custom design. Structural design. Automatic synthesis. Physical design. Advanced CMOS processes. Floor planning. Layout design. Placement. Routing. Structure of a transistor. Parasitic effects. Sources of noises and interference. Techniques for removing noise and disturbances from system to physical (layout) level. Packaging. Verification.		
Practical teaching (exercises, OFE, study and research	Within the course students will design a specifically electronic integrated circuit (from functional description to preparation of data necessary for production) using the Cadence and Synopsis design tools.		
Textbooks/references			
1	V. Litovski, Projektovanje elektronskih kola, Nova Jugoslavija Vranje, 2000, ISBN 86-7369-015-3.		
2	Weste, N.H.E., Harris, D., CMOS VLSI Design A Circuit and Systems Perspective, Fourth edition, Addison-Weslwy, Pearson Education, Inc., 2010, ISBN 10: 0-321-54774-8.		
3	Dokić B., Petković P., Analysis and design of CMOS digital integrated circuits (in Serbian), Academic Mind, Belgrade, 2017, ISBN 978-86-7466-696-8		
4	Saint C., Saint J., IC Mask Design, Essential Layout Techniques, McGraw-Hill, 2002, ISBN 0-07-13899.		
5	Razavi, B.,Design of Analog CMOS Integrated Circuits, Mc Graw Hill India; 2nd edition (July 1, 2017), ISBN-10: 938706784 Хи факултет Ниш, Фебруар 2010.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations, seminars, practical work			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	30
Colloquia			
Projects	70		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Simulation and Optimization of Electronic Circuits and Systems		
Lecturer (for lectures)	Petković M. Predrag		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Adoption and systematization of knowledge about algorithms for analysis and optimization of analogue, simulation of digital as well as mixed signal circuits. Adopting advanced knowledge in modeling electronic devices.		
Course outcomes	Simulation of analog circuits: Domains of abstraction: DC, AC, TR time domain. Algorithms for simulation. Concepts of equation formulation for the analysis of electronic circuits. Algorithms for simulation. Simulation of linear resistance circuits. Frequency domain and s-domain. Simulation of non-linear resistance circuits. Simulation of linear reactive circuits. Simulation of non-linear reactive circuits. Simulation of car with distributed parameters. Methods of Modeling Electronic Components. Characteristic examples of the model: diode, transistors and four-layer structures. Algorithms for simulation of digital circuits. Signal and operator modeling. Modeling the delay. Asynchronous simulation. The principle of the selection of roads and the next event. Simulation of cars with mixed signals. Generating power supply and methods for estimating power and delay. Optimization of electronic circuits: Significance of weight function. Optimization procedures based on the Newton's algorithm. Statistical optimization methods. Simulated cure. Evolutionary algorithms. The notion of tolerance and yield. Deterministic and statistical analysis of tolerances.		
Course outline			
Theoretical teaching	Simulation of analog circuits: Domains of abstraction: DC, AC, TR time domain. Simulation algorithms. Concepts of equation formulation for the analysis of electronic circuits. Simulation of linear R circuits. Frequency domain and s-domain. Simulation of non-linear R circuits. Simulation of linear reactive circuits. Simulation of non-linear reactive circuits. Simulation of circuits with distributed parameters. Methods of Modeling Electronic Devices. Characteristic examples of the model: diode, transistors and four-layer structures. Algorithms for simulation of digital circuits. Signal and operator modeling. Delay modeling. Asynchronous simulation. The route selection and the next (subsequent) event principles. Simulation of mixed signals circuits. Methods for estimating power and delay. Optimization of electronic circuits: Significance of weight function. Optimization procedures based on the Newton's algorithm. Statistical optimization methods. Simulated anealing. Evolutionary algorithms. The notion of tolerance and yield. Deterministic and statistical analysis of tolerances.		
Practical teaching (exercises, OFE, study and research	Practice, research work.		
Textbooks/references			
1	V. Litovski, Projektovanje elektronskih kola, Nova Jugoslavija Vranje, 2000, ISBN 86-7369-015-3.		
2	V. Litovski and M. Zwolinski, VLSI Circuit Simulation and Optimization, Chapman and Hall, London, 1997, ISBN 0 412 63860 6.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Individual projects and research papers.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**

Activity during lectures		**Written exam**	
Exercises		**Oral exam**	30
Colloquia			
Projects	70		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Data Communication and Networking		
Lecturer (for lectures)	Đorđević Lj. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The goal of the course is for students to gain understanding and knowledge in the area of data communication and networking with emphasize on: a) advanced concepts and trends in computer-based systems for efficient and high-speed data communication over various communication media; b) wireless ad-hoc and mobile communications, and wireless sensor networks.		
Course outcomes	Upon completing this course, students are expected to have comprehensive understanding of: a) current data networking technologies and trends; b) various data network architectures; c) various data networking protocols and their applications. Students should also be able to compare different data networks and to perform high level design of data networks.		
Course outline			
Theoretical teaching	Data communications, networks, protocols and standards. Network Models, OSI Model, TCP/IP protocol suite. Physical layer, media and characteristics. Data and signals. Link layer and protocols: error detection and correction, medium access control, flow control, local area networks, Ethernet, IEEE 802.11, Bluetooth. Industrial local area networks. Networking devices. Network layer: addressing, internet protocol, IPv6, routing: unicast, multicast and broadcast routing, intra- and inter-domain routing. Transport layer: UDP and TCP, flow control, congestion control, and quality of service. Application layer: client-server architecture, overview of application protocols. Network management protocols. Multimedia communications: streaming stored audio/video, streaming live audio/video, protocol for multimedia communications. Security: basic principles of cryptography, security services, message confidentiality and integrity, authentication, digital signature, key management. Mobile ad-hoc networks, routing in ad-hoc networks, wireless sensor networks.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	B. A. Forouzan, Data Communications and Networking, 4/e, McGraw-Hill, 2007		
2	J. F. Kurose, K. W.Ross, Computer Networking: A Top-Down Approach Featuring the Internet, 3th Edition, Pearson Education, 2007.		
3	Technical papers from major networking journals and conferences.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, seminars, assignments, and class discussions. Independent and team work of students in solving research-oriented tasks.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Approximation Methods		
Lecturer (for lectures)	Stančić Z. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The expansion and upgrade of the basic knowledge acquired in the field of analog and digital signal processing. A new approximation methods study as a basic bilding block in analog and digital filter design.		
Course outcomes	Students gain the necessary level of theoretical and practical knowledge to successfully answer any specific requirements related to the design, modeling, performance evaluation, estimation of sensitivity, optimization of the filter function, optimization of implementation structure, realization, practical application and verification of analog and digital filter systems.□		
Course outline			
Theoretical teaching	The approximation problems. The magnitude approximation methods. Maximally flat characteristics. Equiripple characteristics. Least-squares error approximation. The transitional characteristics. Other methods of magnitude approximation. Phase characteristic approximation methods. Maximally flat phase characteristics and group delay characteristics. Phase and group delay equiripple characteristics. Interpolation technique in phase approximation. Simultaneous magnitude and phase approximation. Phase and magnitude correctors. The other phase approximation methods. Time domain approximation methods. Equiripple approximation. Interpolation techniques. The other approximation methods. Direct approximation in the z-domain. Hilbert transformer. □		
Practical teaching (exercises, OFE, study and research	The approximation methods in time domain. Min-max approximation. Least square error approximation. Interpolation techniques. The other approximation methods. Interpolation in z domain. The Hilbert transformer. Digital differentiators .		
Textbooks/references			
1	S. Mitra, Digital signal processing A computer based approach, McGraw-Hill, 2006.		
2	Jon G. Proakis, Dimitris Manolakis, Digital Signal Processing, Pearson, 2007.		
3	J.Proakis and D.Manolakis, Digital signal processing: principles, algorithms and applications,1988.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, auditory exesrcises,consultation□			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	30
Exercises		**Oral exam**	40
Colloquia			
Projects	30		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Artificial Intelligence in Engineering		
Lecturer (for lectures)		Andrejević-Stošović V. Miona		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Acquiring knowledge in the field of artificial intelligence with special attention to artificial neural networks concept. Training for independent use of these concepts to solve problems in electrical engineering.			
Course outcomes	Acquiring competence in applying of artificial neural networks in design, testing and diagnosis of electronic circuits and systems. Students are expected to learn fundamental algorithms for neural networks training, as well as handling software for neural networks utilization.			
Course outline				
Theoretical teaching	Artificial intelligence concept. Artificial intelligence based on production rules. Artificial neural networks. Natural nervous system. Neuron. Synapse. Neuron model. Artificial neural networks architectures. Training. Perceptron. Possibilities and algorithms for perceptron training. Multi-layer neural networks. Reccurent neural networks. Types, training and application problems. Procedures of dynamic training. Genetic algorithms. Artificial neural networks realization. VLSI implementation of analog neural networks. Digital realization. Boltzmann machine. Neuro-fuzzy networks and their application.			
Practical teaching (exercises, OFE, study and research	Specialized ICs that implement neural networks. The application of neural networks in CAD, image and signal processing, in OCR systems, in speech recognition, in robotics, in civil and military security systems. The hardware implementation of artificial neural networks on FPGAs.			
Textbooks/references				
1	Genetic Algorithms in Applications, Editor Rustem Popa, In-tech, March 2012, ISBN 978-953-51-0400-1.			
2	Andrejević, M., „Neuronske mreže u modelovanju“, Zadužbina Andrejević, Beograd, 2004.			
3	Milenković, S., „Veštačke neuronske mreže“, Zadužbina Andrejević, Beograd, 1997.			
4	Haykin, S., “Neural Networks: A Comprehensive Foundation”, Macmillan College Publishing Company, Inc., 1994.			
5				
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, laboratory practice, individual projects.			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures			**Written exam**	
Exercises			**Oral exam**	50
Colloquia				
Projects		50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	RF Integrated Circuits		
Lecturer (for lectures)	Jovanović S. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to technology of RF integrated circuits production, design flow and verification. Description of the process for measuring and testing the fabricated integrated circuits. Introducing to RF designers job in a standard working environment. Usage of specialized software tools for RF circuit design.		
Course outcomes	Students need to acquire theoretical and practical knowledge that is necessary for realization of complex RF circuits on-chip.		
Course outline			
Theoretical teaching	BiCMOS technology for RF and analog circuits. Design kit, installation, design rules, the most important parameters. Library elements, schematic symbols, simulation models, the layout. Library cells. Creation of new cell. Layout drawing. Pad in RF integrated circuits, bonding, chip packaging. Wires on a chip as matching networks elements and microstrip filters. Electromagnetic simulation of the layout. Equivalent reflection layout parameters. Layout vs. schematic verification (LVS). Design rules check (DRC). Design simulation. GDSII format. Fabrication.		
Practical teaching (exercises, OFE, study and research	Design examples: low-noise amplifiers, mixers, oscillators, PLL circuits.		
Textbooks/references			
1	Benzad Razavi, RF Microelectronics, Second Edition, Prentice Hall, 2012.		
2	R. Gilmore and L. Besser, Practical RF Circuit Design for Modern Wireless Systems, Artech House, Boston, 2003.		
3	R. Ludwig, P. Bretchko, RF Circuit Design: Theory and Applications, Prentice Hall, 2000.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, exercises, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Processing of Audio Signal		
Lecturer (for lectures)	Stančić Z. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introducing students with basic and advanced methods of digital audio signal processing.□		
Course outcomes	Training students for independent digital audio signal processing by using existing advanced software . Design of digital filters for introducing various audio effects		
Course outline			
Theoretical teaching	Basic audio signal formats. Sampling and reconstruction of signal. A/D and D/A conversion. Adequate determination of sampling frequency and transformation. Effective calculation of the fast Fourier transformation. Down-sampling and up-sampling. Digital filter banks. Spectral analysis. Parametric and nonparametric filter design methods. Examples of application of digital signal processing in analysis and synthesis of speach and music signals, and discrete analytical signals.□		
Practical teaching (exercises, OFE, study and research	Time domain approximation methods. Equiripple error approximation. Least-squares approximation. Interpolation techniques. The other approximation methods. Direct approximation in z-domain. Hilbert transformator. Digital differentiators. Modeling of musical instruments. Echo generators, reverberators. Shelving filters. Various time delay filters.□		
Textbooks/references			
1	M.Milić, Audio systems (in Serbian), Akademska misao, Beograd, 2011.		
2	Lj. Milić и Z. Dobrosavljević, Introduction to digital signal processing (in Serbian), Akademska misao, 2009.		
3	L. Milic, Multirate filtering for digital signal processing: MATLAB applications, Information Science Reference-Imprint of: IGI Publishing, 2008.		
4	Jon G. Proakis, Dimitris Manolakis, Digital Signal Processing, Pearson, 2007.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, auditory exesrcises,consultation□			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	30
Exercises		**Oral exam**	40
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Circuits and Systems Design		
Lecturer (for lectures)	Dimitrijević A. Marko		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring and systemizing knowledge about procedures, methods and tools for digital electronic circuits and systems design. Acquiring advanced knowledge of electronic design automation (EDA) tools for submicron CMOS technologies.		
Course outcomes	Acquiring competence for designing digital circuits and systems, including all aspects that follow this process. Students will learn the design and production processes of digital circuits and systems, from the behavioral model of the circuit/system to its actual realization.		
Course outline			
Theoretical teaching	Digital circuits design according to possibilities and limitations: area, consumption, speed, choice of architecture, bus width, protocols. Signal integrity. Different reference voltage levels coupling. Power routing with multiple power levels on the chip. Power density distributions in the integrated circuit. Power management in the circuit. Clock and synchronization. Design for testability. Design for production. Application of IP blocks. Makrocells. Circuit/system prototyping on FPGA.		
Practical teaching (exercises, OFE, study and research	Design of digital integrated circuits using tools that represents industrial standards for design of integrated circuits - Cadence Digital Design.		
Textbooks/references			
1	V. Litovski, Electronic Circuit Design (in Serbian), Nova Jugoslavija, Vranje, 2000, ISBN 86-7369-015-3.		
2	Weste, N.H.E., Harris, D., CMOS VLSI Design A Circuit and Systems Perspective, Addison-Weslwy, Pearson Education, Inc., 2005, ISBN 0-321-26977-2.		
3	P. Petković, et.al., Laboratory Exercises in Design of electronic circuits and Design of Digital Integrated Circuits (in Serbian), Faculty of Electronic Engineering Niš, February 2010.		
4			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	lectures, student research work			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Embedded Systems Design		
Lecturer (for lectures)	Nikolić R. Tatjana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The goal of this course is to highlight the crucial development directions and new challenges during design of embedded systems including design for low power, optimization of hardware and software, SoC and MPSoC design and configurable processors.		
Course outcomes	Student's ability to design hardware and software part of embedded systems and correctly evaluate the cost-performance ratio.		
Course outline			
Theoretical teaching	Embedded versus general purpose processors. Methodologies of designing hardware and software embedded systems. Calculation models. Limitations and challenges (high reliability, high performance, low cost, low power). Hardware-software codesign. Programming and code optimization. Tools for development and testing. Embedded operating systems. Task scheduling and execution in real time. Selection and installation of the operating system. Verification. Multiprocessor architectures. Types. Homogeneous and heterogeneous multiprocessor structures. Process elements. Interconnection networks. Memory systems. Phisical distribution. Design methodologies and algorithms. Multiprocessor software. Operating systems. Services and middleware. Verification of design. SoC design. The design of complex SoCs at system level. Configurable processors. Software and hardware aspects. Application specific processors. Automatic configuration of processor and instruction set. Compilers. Accelerator units. MPSoCs. Designing SoCs using cores and configurable cores. Buses and networks on chip. Operating systems for MPSoC. Testing and verification. Typical applications.		
Practical teaching (exercises, OFE, study and research	Preparation of seminar papers in the field of application specific processor, input-output modules with specific purpose, interconnection on- and off-chip networks, and multiprocessor systems-on-chip. Evaluation of system performance in terms of operating frequency, power consumption, and the silicon area.		
Textbooks/references			
1	R. Kamal, Embedded Systems, McGraw Hill, 2008.		
2	Alan Holt, Chi-Yu Huang, Embedded Operating Systems, A Practical Approach, Springer-Verlag, 2014.		
3	William J. Dally, Curtis Harting, Digital Design: A system approach, Cambridge University Press, 2012.		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching is held in a form of lectures and mentoring work with students. Independent and team work of students during solving tasks within research projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	System-on-Chip Design		
Lecturer (for lectures)	Milić Lj. Miljana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Training students for designing integrated circuits at the system level on the chip using standard design tools.		
Course outcomes	The designer is competent to independently design a system on a chip with detailed knowledge of the problems that characterize the design of the system on the chip. The designer acquires knowledge to practically independently applies one of the industrial design standards.		
Course outline			
Theoretical teaching	Classification of electronic systems. Specification of the systems on the chip. Data flows in the system on the chip. The integrity of the signal to the system on the chip. Effects of long lines. Application of different design methodologies on a single chip. Hierarchical levels of design. Application of IP blocks. Functional verification of the project. Physical verification and analysis.		
Practical teaching (exercises, OFE, study and research	Lectures and public defense of student scientific research.		
Textbooks/references			
1	Dokic B., Integrated circuits (in Sergian), Faculty of Electrical Engineering in Banja Luka, Bosnia and Herzegovina, 1999.		
2	Baker, R. J. CMOS Mixed-Signal Design, IEEE Press, Piscataway, NJ, USA, 1988.		
3	Wolf, W, Modern VLSI Design: System-on-Chip Design, Prentice Hall, N.Y. USA, 2006.		
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Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Presentations on specific topics, seminars and projects

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	DSP Architectures and Algorithms		
Lecturer (for lectures)	Nikolić R. Tatjana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The goal of this course is to involve students to theoretical and practical knowledge required for designing hardware for implementation of algorithms in the field of digital signal processing and software development for DSP processors.		
Course outcomes	Competence of students to use DSP processor for digital signal processing in real time and modern tools for efficient design and implementation of complex DSP applications. Competence for hardware design of basic DSP blocks and usage of DSP IP cores for the implementation in complex DSP applications.		
Course outline			
Theoretical teaching	Specificity and DSP processor architecture. Areas of DSP applications. Data presentation and arithmetic, the effect of finite length words, aspects of the program, working in real time, and hardware interface. Programming the DSP processors in assembly language and higher programming language. DSP for use in fixed point format. DSP in floating point format. DSP for embedded applications. DSP on FPGA. Code optimization. Hardware realizations: digital filters (FIR and IIR), Discrete Fourier Transform, CORDIC, algorithms for cryptography, digital modulation and demodulation circuits.		
Practical teaching (exercises, OFE, study and research	It is planned that students individually do seminar papers in the following areas: 1) manipulation with the numbers in fixed- and floating-point format, 2) understanding the capabilities of modern development tools for the design, 3) digital filter, 4) FFT, 5) convolution and correlation, 6) interpolation and decimation, 7) adaptive filtering, and 8) interface with DSP processor.		
Textbooks/references			
1	Shoab Ahmed Khan, Digital Design of Signal Processing Systems: A Practical Approach, Wiley, 2011.		
2	U.M-Baese, Digital Signal Processing with Field Programmable gate Arrays, Springer-Verage, Berlin, 2007.		
3			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching is held in a form of lectures and mentoring work with students. Independent and team work of students during solving tasks within research projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electronic Circuits Testing		
Lecturer (for lectures)	Milić Lj. Miljana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The student learns the mechanisms of defect generation in electronic circuits (analogue, digital and mixed-signal circuits), as well as procedures for synthesizing test signals for testing integrated electronic circuits.		
Course outcomes	The student will be familiar with the causes of defects in the integrated electronic circuits and will be able to create a test signal to detect defects in integrated electronic circuits (analogue, digital and mixed-signal circuits). Also, the student will learn the design techniques that facilitate the testing process both in the laboratory and in the mass production of integrated circuits.		
Course outline			
Theoretical teaching	Defect models in analog and digital circuits. Concurrent simulation of defects. Digital circuits testing. Testing of combinational, sequentials and circuits with regular topology. Automation of test pattern generation. Testing and simulation of delay defects. Testing of systems with mixed signals. Design for testability. Basic Concepts of the Boundary Scan. Built-in self-test. Testing of electronics devices.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	V. Litovski, Basics of Electronic circuit testing (in Serbian), Facylty of electronic engineering, University of Niš, 2010, ISBN 978-86-85195-71-6		
2	V. Litovski, Examples of electronic circuits testing (in Serbian), Facylty of electronic engineering, University of Niš, 2010, ISBN 978-86-6125-008-8.		
3	М. Милић, ет. ал, Практикум лабораторијских вежби из тестирања и дијагностике електронских кола, Електронски факултет, Ниш, 2010, ИСБН 978-86-6125-007-1.		
4	Abramovici, M., et all, Digital system testing and testable design, Computer Science Press, New York, USA, 1990.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations and Public Defense of Student Scientific Research			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Reconfigurable Systems		
Lecturer (for lectures)	Đorđević Lj. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The course objective is to teach students with architectures and design principles of reconfigurable systems and their applications in computing and embedded systems, including: a) fundamentals of reconfigurable system design at low-, middle- and high-level of abstraction; b) practical aspects of reconfigurable computing and implementation constraints; c) typical applications of reconfigurable systems.		
Course outcomes	After successful completion of this course, students are expected to be able to design and implement fully and partially reconfigurable systems of small- to medium complexity on FPGA platforms.		
Course outline			
Theoretical teaching	Introduction to Reconfigurable Systems. Overview of the architecture of modern FPGA circuits. Trends of development. Design flow, methodologies and design tools. Optimization of the HDL code for FPGA synthesis from the aspect of performance, complexity and energy consumption. Mapping RTL structures to FPGA and implementation: scheduling and binding. Coarse-grained reconfigurable systems and multi-FPGA systems. Hybrid architectures: soft-microprocessors, hardware/software co-design. Comparison of FPGA and multicore architectures. Implementation of arithmetic circuits in FPGA. Applications of reconfigurable systems in fields of: bioinformatics, digital signal processing, image processing, cryptography, molecular dynamics, fluid dynamics, and high-reliability systems. Advanced Topics: dynamic reconfigurability, and partial reconfigurability.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	S. Hauck, A. DeHon, Reconfigurable Computing: The Theory and Practice of FPGA-Based Computation, 2008.		
2	S. Kilts, Advanced FPGA Design, Architecture, Implementation, and Optimization, John Wiley & Sons, Inc., 2007.		
3	Technical papers from major journals and conferences in the field of reconfigurable computing.		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, seminars, assignments, and class discussions. Independent and team work of students in solving research-oriented tasks.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Synthesis of Filters		
Lecturer (for lectures)	Nikolić V. Saša, Stančić Z. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The expansion and upgrade of the basic knowledge acquired in the field of analog and digital signals processing and method of filter transfer function approximation with goal to adopt new techniques which require specific approximations and specific implementations. At the same time optimal filter implementation are analyzed. Analysis of the impact of the finite word length.		
Course outcomes	Students gain the necessary level of theoretical and practical knowledge to answer any specific requirements related to the design, modeling, performance estimation, optimization, implementation, and verification of the practical application of filter systems.		
Course outline			
Theoretical teaching	Transfer function. Characteristic function. Reflection coefficient. z and y parameters of the two port network. Synthesis of passive filters. Synthesis of polynomial filters. Synthasis of filters with finite transmission zeros.Minimum phase filters. Synthesis of mechanical, ceramic and crystal filters. Filters with distributed parameters. Synthesis of active RC filters. Filter configurations. Impedance converters. Realization of biquad transfer function. Active RC network with distributed parameters in the integrated technology. Digital filters. Transfer function of the digital filter. Bilinear z transform. The basic filter configurations. Recursive and nonrecursive digital filters. Direct methods of approximation in the z-domain. IIR and FIR filter function. Filter realization. Properties of different configurations. Sensitivity. Decompozition. Tipical filter realization problems. Applying of MATLAB, MATHEMATICA, WORKBENCH, FILTER.		
Practical teaching (exercises, OFE, study and research	Recursive and nonrecursive digital filters. Direct methods of approximation in the z-domain. IIR and FIR filter transfer functions. Implementation of filters. The properties of different configurations. Sensitivity. Decomposition. Typical problems in the implementation of filters. Application of Matlab, Mathematica, WORKBENCH, FILTER.		
Textbooks/references			
1	A. Antoniou, Digital filters: Analysis, design and applications, second edition, Prentice-hall, 1975.		
2	S. Mitra, Digital signal processing A computer based approach, McGraw-Hill, 2006.		
3	Jon G. Proakis, Dimitris Manolakis, Digital Signal Processing, Pearson, 2007.		
4	L Milic, Multirate filtering for digital signal processing: MATLAB applications, Information Science Reference-Imprint of: IGI Publishing, 2008.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, auditory exercices, projects, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		RF Systems Architectures		
Lecturer (for lectures)		Jovanović S. Goran		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Acquainted with the advanced techniques for high-frequency circuits and systems design. Modern architecture of transmitter and receiver. Gaining practical knowledge of radio links design, antennas design and radio wave propagation.			
Course outcomes	Students need to acquire theoretical and practical knowledge necessary for the realization of complex projects in wireless communication.			
Course outline				
Theoretical teaching	Transmitter and receiver architectures. Technologies for RF circuits production.□ Optimization of noise factors, intermodulation distortion, and stability factors in low noise amplifiers and balancing mixers. Jitter and phase noise in voltage controlled oscillators with negative transconductance and PLL frequency synthesizers. RF power amplifiers and duplexers. Multi standard transceiver. Radar, wireless sensor networks, special antenna systems, RFID, navigation systems.□			
Practical teaching (exercises, OFE, study and research	Radio transceiver project. RFID reader project. Doppler radar project.			
Textbooks/references				
1	Benzad Razavi, RF Microelectronics, Prentice Hall, 1998.			
2	P.-I. Mak, Seng-Pan U, R. P. Martins, Analog-Baseband Architectures and Circuits for Multistandars and Low Voltage Wireless Transceivers, Springer, 2007.			
3	R. Ludwig, P. Bretchko, RF Circuit Design: Theory and Applications, Prentice Hall, 2000.			
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Computer Vision		
Lecturer (for lectures)	Nikolić V. Saša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	To train students for research work in the field of computer vision. Introduce advanced algorithms in the field of digital image processing and machine learning.		
Course outcomes	Practically implementation of state of the art algorithms in the field of digital image processing and machine learning for content based image recognition and classification.		
Course outline			
Theoretical teaching	Extracting features in an image - global and local features (CLD MPEG-7, MPEG-7 EHD, LBP, SIFT). The classification features (k-means, Bayesian methods, SVM). Search and classification based on image content. Fast search techniques using machine learning. Detection and identification of 2D objects in an image. Object tracking in video sequences. Stereovision. Basics of 3D vision.		
Practical teaching (exercises, OFE, study and research	Implementation of algorithms in Matlab.		
Textbooks/references			
1	David A. Forsyth, Jean Ponce, "Computer Vision: A Modern Approach", 2nd edition, 2011.		
2			
3			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, individual projects, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Ultrasonic Technique		
Lecturer (for lectures)		Mančić D. Dragan		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Expanding and upgrading the fundamental knowledge acquired in the field of ultrasonic technique and guidance towards the adoption of new techniques required by concrete and specific applications which are subject of interest to students.			
Course outcomes	Students gain the necessary theoretical and practical knowledge to meet any specific request in development, modeling, performance assessment, optimization, realisation, control, practical application and verification of the various devices of ultrasonic technique mainly of the various sandwich transducers and electronic generators.			
Course outline				
Theoretical teaching	Piezoelectric ceramics. Modelling of piezoelectric ceramics. Development of ultrasonic waveguide concentrators and sonotrodes. Modeling of metal resonators. Development, modeling and optimization of the power ultrasonic transducers. Development, modeling and optimization of the power electronic ultrasonic generators. Basic applications of power ultrasound. Ultrasonic systems for cleaning and welding.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	M.Radmanovic, D.Mancic, "Design and modelling of power ultrasonics transducers", MP Interconsulting, Le Lockle, Switzerland, 2004.			
2	D.Ensminger, L.J.Bond, "Ultrasonics: Fundamentals, Technologies, and Applications", CRC Press, 2011.			
3	J.David, N.Cheeke, "Fundamentals and Applications of Ultrasonic Waves", CRC Press, 2012.			
4	D.Mancic, V.Paunovic, “Application of impedance spectroscopy for electrical characterization of La doped BaTiO3-ceramics” (in Serbian), Faculty of Electronic Engineering Nis, Edition: Monographies, Nis, 2012.			
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching is held in lectures while simultaneously mentoring students. Individual and team work of students takes place during their practical and scientific and research work on the defined projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Solid State Physics		
Lecturer (for lectures)		Ristić S. Goran		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Introducing students to basic processes in solid states, including conductors, semiconductors and dielectrics.			
Course outcomes	Mastering the theoretical knowledge related to the structure and properties of solid states, as well as the transport of charge carriers			
Course outline				
Theoretical teaching	Theoretical lectures will take place in the following areas: Physical characteristics and classification of solid states, crystal lattices, interatomic connections, zonal theory of solid states, electronic states in a periodic crystal, thermal motion of the crystal lattice, transport and optical charecteristics, properties of dielectrics. Semiconductors, electronic transport processes, diffusion and recombination processes. Magnetic properties of solid bodies. Superconductivity.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	D. Tjapkin, Physical electronics and solid-state electronics, ETF, Belgrade, 1994 (in Serbian)			
2	C. Kittel, Introduction to Solid State Physics, John Wiley & Sons, 1976			
3	N. Ashcroft, N. Mermin, Solid state pysics, Harcourt College Publishing, NY, 1978			
4				
5				
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations on specific topics, seminars and projects			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures			**Written exam**	
Exercises			**Oral exam**	60
Colloquia		40		
Projects				

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Physics of Ionized Gases		
Lecturer (for lectures)	Ristić S. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Get to know the basic processes that lead to the formation of charged particles in the gas and their transport. Getting to know about the breakdown of gases, tinnitus, sparks, coronas and arched discharge.		
Course outcomes	Mastering the theoretical knowledge of the process of the formation and transport of charged particles into a low ionized gas.		
Course outline			
Theoretical teaching	Theoretical lectures will take place in the following areas: Formation and disappearance of particles into a weakly ionized gas. Drift, energy and diffusion of charged particles. Breakdown in gases in the fields of different frequency band. Stable and unstable dissipation. Spark, corona and arched discharge. Solving the kinetic equation in a weakly ionized gas in the presence of an electric field. Physical mechanisms that lead to discharge and which are present in various types of discharge		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	A. Engel, Electric Plasmas: Their nature and users, Taylor and Frencis Ltd, London&New york, 1983		
2	G. Francis, Ionization Phenomena in Gases, Butterworthes Scientific Publication, London, 1960		
3	M.A. Lieberman and A.J. Lichtenberg, Principles of plasma discharges and materials processing, John		
4	Wiley&Sons Inc., New York, 1994		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations on specific topics, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	60
Colloquia	40		
Projects			

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Photonics		
Lecturer (for lectures)		Golubović M. Snežana		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Ensuring the understanding of the dual nature of light and its characteristics (generation, transport, monitoring, detection and application).			
Course outcomes	Training for work in the field of photonics and its related fields (electronic optics, optoelectronics), understanding of the vital role of light in a wide range of domains, with the possibility of developing and mastering new techniques and skills.			
Course outline				
Theoretical teaching	The dualism. Electromagnetic nature of light. Interference, diffraction and polarization. The interaction of light and matter. Corpuscular nature of light and other electromagnetic radiation. Photoelectric and Compton effect. Optical instruments. Non-laser and laser light.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	D.V. Sivuhin, Optics, Moscow, 1980 (in Russian)			
2	Mark Fox, Optical Properties of Solids, Sheffield, 2001			
3				
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, exercises, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Radiation Physics		
Lecturer (for lectures)	Ristić S. Goran, Golubović M. Snežana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introducing students with ionizing and non-ionizing radiation, radiation detection, biological effects and radiation protection		
Course outcomes	Mastering theoretical knowledge related to the types of radiation, their influence on living and non-living matter, radiation detection, and protection against radiation.		
Course outline			
Theoretical teaching	Types and sources of ionizing radiation, ionizing radiation effects on living and non-living matter, dosimetric quantities and units. Radiation detection and protection. Characteristics and types of non-ionizing radiation and its influence on living organisms.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G. Knoll, Radiation Detection and Measurement, John Wiley & Sons, 2000		
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations on specific topics, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	60
Colloquia	40		
Projects			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electrical discharge of gases		
Lecturer (for lectures)	Živanović N. Emilija, Pejović M. Milić		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Basic concept, required for understand the physical processes that take place during breakdown and discharge, as well as in the practical applications. An additional impact will be focused to the field of practical applications of different types of gas components. Characterization of gas components, methods of measurements and statistical analysis of the obtained results.		
Course outcomes	Introduction to theoretical and practical knowledge required for characterization, measurement methods and statistical analysis of the obtained results.		
Course outline			
Theoretical teaching	Electric breakdown and discharge in gases. Processes in noble gases, nitrogen and air. Processes on electrodes. Breakdown probability. Breakdown voltage. Electrical breakdown time delay. Analysis of the memory effect in gases based on memory curves.		
Practical teaching (exercises, OFE, study and research	Practical classes take place in the laboratory. Demonstration and introduction with existing electronic systems for testing and characterization of different types of gas devices. Possibility of additional realization of parts as well as complete measurement systems.		
Textbooks/references			
1	Momčilo Pejović, MIlić Pejović, „Električni proboj gasova-merni sistemi i eksperimentalna istraživawa“, Elektronski fakultet, Niš, 2009.		
2	Emilija Živanović, „Procesi inicirani električnim probojem i pražnjenjem odgovorni za memorijski efekat u azotu i vazduhu“, doktorska disertacija, Elektronski fakultet, Univerzitet u Nišu, 2014.		
3	Emilija Živanović, „Fizičko-hemijski procesi koji dovode do iniciranja električnog proboja u azotu na niskim pritiscima“, magistarska teza, Elektronski fakultet, Univerzitet u Nišu, 2004.		
4	Y. P. Rayzer, „Gas Discharge Physics“, Berlin: Springer, 1991.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching takes place through lectures and laboratory exercises and consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	10	**Oral exam**	50
Colloquia	20		
Projects	20		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Devices of Vacuum and Gas Electronics		
Lecturer (for lectures)	Ristić S. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to students with the types and principles of work of modern components of vacuum and gas electronics		
Course outcomes	Mastering theoretical knowledge related to the physical fundamentals of mechanisms and processes used in modern components of vacuum and gas electronics, as well as the principles of their work		
Course outline			
Theoretical teaching	Theoretical lessons will be delivered through lectures in the following areas: electrons in electric and magnetic fields, electronic emissions, electronic cannons and mirrors. Electronic tubes controlled by gratings. Microwave components and circuits. Clistrons, multiplying components. Photoelectronic components, voltage regulating tubes, gas rectifier tubes, tiratrons, plasma displays, gas sources of light.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	A. Engel, Electric Plasmas: Their nature and users, Taylor and Frencis Ltd, London&New york, 1983		
2	M. Sedlacek, Electron Physics of Vacuum and Gaseous Devices, John Wiley&Sons, 1996		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations on specific topics, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	60
Colloquia			
Projects	40		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Medical Physics		
Lecturer (for lectures)	Ristić S. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the use of ionizing and non-ionizing radiation in medicine, as well as the principle of basic methods of medical diagnostics.		
Course outcomes	Knowledge of diagnostic and therapeutic methods in medicine based on ionizing and non-ionizing radiation, as well as devices used for this purpose.		
Course outline			
Theoretical teaching	Medical diagnostics. X-rays and X-ray characteristics and their application in medicine. Radiography and fluoroscopy, mammography, X-ray, computer tomography. Digital Flat Panel X-ray Appliances. The production and the characteristics of ultrasound and its application in medicine. Principle of magnetic resonance, and its application in medical diagnostics. Use of radioisotopes in medical diagnostics and radiotherapy. PET diagnostics. Electrocardiography, Laser application in medicine. Application of radiofrequency and optical radiation in medical diagnostics and therapy. Radiotherapy devices.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G. S. Ristic, Medical Physics, Script, Faculty of Electrical Engineering Nis (in Serbian)		
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations on specific topics, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	70
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Semiconductor Devices and Technologies		
Lecturer (for lectures)	Prijić P. Aneta		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Objectives of the course are focused on: - Detailed analysis of physical processes in semiconductor materials; - In-depth study of the structure and principles of the basic semiconductor devices functioning; - Introduction to the structures and functioning principle of semiconductor devices based on heterojunctions and compound semiconductors; - Understanding the functioning of microwave and photovoltaic components; - Introduction to advanced technologies for semiconductor devices and integrated circuits fabrication.		
Course outcomes	Learning outcomes allow a student to: - Visualize the effects of high doping of the semiconductors through the concept of energy bands; - Explain the interdependence of relations that describe the concentrations and transport of charge carriers in the semiconductor; - Analyze secondary physical and electrical effects that affect the functioning of basic semiconductor devices; - Compare the functioning principles of semiconductor devices based on heterojunctions and semiconductor compounds with basic semiconductor devices; - Explain the functioning of microwave and photovoltaic devices; - Specifies the unique properties of advanced semiconductor devices fabrication techniques.		
Course outline			
Theoretical teaching	Energy bands and carrier concentrations in equilibrium. Effects of a highly doped semiconductor. Transport of charge carriers. Diodes. Silicon bipolar transistors. Bipolar transistors based on heterojunctions. Modeling of bipolar transistors. Field effect transistors based on semiconductor compounds. GaAs MESFETs. Heterojunction Field Effect Transistors (HFETs). MOSFET transistors. CMOS/BiCMOS. SOI and 3D structures. Microwave components. Photovoltaic components. Monocrystalline silicon formation and epitaxial growth. Oxidation and growth of thin films. Diffusion and ion implantation. Photolithography and etching. Integrated devices.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	S. Zee, M. Lee, "Semiconductor Devices - Physics and Technology", 3rd Edition, Wiley, 2012 - selected chapters.		
2	D. Neaman, "Semiconductor Physics and Devices", 4th Edition, McGrawHill, 2011 - selected chapters.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Consulting teaching; Participation in the realization of scientific-research projects; Inclusion in the teaching process at bachelor and master academic studies; Seminars and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	30	**Oral exam**	40
Colloquia			
Projects	30		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Sensors and Actuators		
Lecturer (for lectures)		Vračar M. Ljubomir		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course	Acquiring the knowledge for understanding and application of modern sensors and actuators.			
Course outcomes	Students obtain the in-depth knowledge about operational principles, fabrication and implementation of modern sensors and actuators.			
Course outline				
Theoretical teaching	Classification and terminology of sensors and actuators. Signal processing. Most important sensor types: magnetical, radiation, thermal, mechanical and chemical. Most important actuator types: linear and rotary electromechanical converters, displays, electrical converters. Interface methodologies and circuits. Integration aspects. Manufacturing techniques and material properties. Applications of sensors and actuators.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1				
2	JACOB FRADEN, "HANDBOOK OF MODERN SENSORS: PHYSICS, DESIGNS, and APPLICATIONS" Third Edition, 2011, Springer-Verlag, In Jon S. Wilson (ed.), "Sensor Technology Handbook" Newnes, Elsevier Inc, 2005			
3				
4				
5				
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Auditorial teaching, Laboratory exercise, student tutorials			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**	**Points**	
Activity during lectures	10	**Written exam**		
Exercises		**Oral exam**	60	
Colloquia				
Projects	30			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Technological Processes in Gasses and Vacuum		
Lecturer (for lectures)	Golubović M. Snežana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The acquisition of theoretical knowledge about gases and vacuum in order to introduce to certain technological processes (with particular emphasis on technological processes in microelectronics).		
Course outcomes	Acquired knowledge on technological processes that occur in gases and vacuum, especially on the technological processes in the production of microelectronic devices..		
Course outline			
Theoretical teaching	The properties of gases. Molecular phenomena in the gas. Transport processes in gas. The adsorbed gases. Electric currents in gases. Pumping and vacuum pumps. Measuring the low-pressure gas and vapor. Vacuum systems. Vapor deposition. Nitriding. Cleaning surfaces. Plasma metallurgy. Plasma processes in microelectronics..		
Practical teaching (exercises, OFE, study and research	Seminar work.		
Textbooks/references			
1	VLSI Electronics Microstructure Science, edited by Norman G. Einspruch, Academic Press, 1984.		
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentation on a given topic.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program			Electrical Engineering and Computer Science	
Module			Common	
Type and level of studies			Doctoral studies	
The name of the course			Electromagnetics	
Lecturer (for lectures)			Raičević B. Nebojša	
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**		Elective
Prerequisites	None			
Course objectives	The aim of the subject is that the student upgrades her knowledge of electrostatics and magnetism, learns to apply the most commonly used analytical and numerical methods for calculation of EM fields, as well as to get familiar with existing software packages for solving practical problems in the field of her PhD studies and become capable of doing the PhD thesis.			
Course outcomes	The student is trained to calculate the electromagnetic field of the designed device, and predict or measure the field in its surroundings. He is capable of improving the performance of a devise, increasing its compatibility with other devices, as well as ensuring its safe usage.			
Course outline				
Theoretical teaching	Electrostatics. Stationary and time-varying electromagnetic field. Integral and differential form of Maxwell's equations. Maxwell's equations in the complex domain. Electromagnetic properties of the medium. Boundary conditions. Electromagnetic field potentials in the homogenous media. Painting's theorem. Analytical methods for calculation of the electromagnetic fields - method of separation of variables, application of the complex variable functions (conformal mapping). Numerical methods for calculation of electromagnetic fields - finite different method, finite element method (FEM), finite difference time domain method (FDTD), equivalent electrodes method (EEM), hybrid boundary element method (HBEM). Plane-wave propagation (in vacuum, dielectrics, imperfect conductors, ferrites and layered media). Wave polarization. Propagation of electromagnetic waves. Fresnel's coefficients. TEM, TE and TM guided waves. Electromagnetic radiation and antennas.			
Practical teaching (exercises, OFE, study and research work)	Electrostatics. Stationary and time-varying electromagnetic field. Integral and differential form of Maxwell's equations. Maxwell's equations in the complex domain. Electromagnetic properties of the medium. Boundary conditions. Electromagnetic field potentials in the homogenous media. Painting's theorem. Analytical methods for calculation of the electromagnetic fields - method of separation of variables, application of the complex variable functions (conformal mapping). Numerical methods for calculation of electromagnetic fields - finite different method, finite element method (FEM), finite difference time domain method (FDTD), equivalent electrode method (EEM), hybrid boundary element method (HBEM). Plane-wave propagation (in vacuum, dielectrics, imperfect conductors, ferrites and layered media). Wave polarization. Propagation of electromagnetic waves. Fresnel's coefficients. TEM, TE and TM guided waves. Electromagnetic radiation and antennas.			
Textbooks/references				
1	D. M. Veličković: Electromagnetics (in Serbian) - the first book, Faculty of Electronic Engineering, Niš, 2004.			
2	D. M. Veličković et al., Collection of solved examples from Electromagnetics - I part (in Serbian), Faculty of Electronic Engineering of Niš, Niš, 2000.			
3	D. M. Veličković, F. H. Uhlmann, K. Brandisky, R. D. Stancheva, H. Brauer: Fundamentals of Modern Electromagnetics for Engineering, TU Ilmenau, Germany, 2005.			
4	J. V. Surutka: Electromagnetics (in Serbian), Građevinska knjiga, Beograd, 1966.			
5	Fawwaz T. Ulaby: Fundamentals Applied Electromagnetics, Pearson, Prentice Hall, New York, ISBN-13: 978-0132139311, 2010.			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Lectures and auditive practice classes. Besides board work, multimedial presentations, photographs and video clips are presented. Obligatory consultations with lecturers help successful course material adoption.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	20	**Written exam**	
Exercises		**Oral exam**	40
Colloquia			
Projects	40		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electric Circuits Theory		
Lecturer (for lectures)	Cvetković Ž. Zlata, Vučković N. Ana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Applying the analytical, numerical, and software tools to solve practical problems in the analysis and synthesis of electric circuits.		
Course outcomes	Students are trained to solve practical problems related to the analysis and synthesis of electric circuits using analytical, numerical, and software tools.		
Course outline			
Theoretical teaching	Topological electric circuit analysis. Analysis in time and frequency domain. Analogue circuits with losses. Circuits with distributed parameters. Discrete circuits. Graph theory. Computer aided circuit analysis.		
Practical teaching (exercises, OFE, study and research	Reference collecting. Study the selected chapters. Analysis of a real problem. Independent research work.		
Textbooks/references			
1	Z. Cvetković: "Electrical circuits" (in Serbian), Faculty of Electronic Engineering of Niš, 2016, ISBN 978-86-6125-167-2.		
2	Z. Cvetković, A. Vučković: "Collection of solved problems from Electrical circuits" (in Serbian), Faculty of Electronic Engineering of Niš, 2013, ISBN 978-86-6125-079-8.		
3	M. Potrebić, D. Tošić: ”Collection of solved problems from Electrical circuits theory” (in Serbian), 2012, Akademska misao, Belgrade.		
4	S. Karris: "Circuit Analysis I with MATLAB Applications", Orchard Publications, Fremont, California, 2004.		
5	S. Karris: "Circuit Analysis II with MATLAB Applications", Orchard Publications, Fremont, California, 2003.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations, semestral work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Antennas and Electromagnetic Waves Propagation		
Lecturer (for lectures)		Raičević B. Nebojša, Perić T. Mirjana		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites	None			
Course objectives	The aim of the subject is that the student learns to apply the most commonly used analytical and numerical methods for calculation of the electromagnetic field of different antenna structures.			
Course outcomes	Student is trained to calculate electromagnetic field of radiating structures and measure field in the surroundings of transmitting and receiving antennas. The candidate is capable of improving performances of antenna structures and systems, and possesses knowledge about antenna application in electromagnetic compatibility.□			
Course outline				
Theoretical teaching	Electromagnetic properties of media. Spherical, cylindrical and plane electromagnetic waves (in the free space, dielectrics, and stratified media). Wave polarization. Propagation of electromagnetic waves. Fresnel coefficients. TEM, TE and TM guided waves. Electromagnetic radiation and antennas. Current distribution. Hallén's integral equation. Pocklington's integral equation. Radiation pattern. Antenna gain. Radiation resistance. Transmitting and receiving antenna. Antenna arrays.			
Practical teaching (exercises, OFE, study and research	Electromagnetic properties of media. Spherical, cylindrical and plane electromagnetic waves (in the free space, dielectrics, and stratified media). Wave polarization. Propagation of electromagnetic waves. Fresnel coefficients. TEM, TE and TM guided waves. Electromagnetic radiation and antennas. Current distribution. Hallén's integral equation. Pocklington's integral equation. Radiation pattern. Antenna gain. Radiation resistance. Transmitting and receiving antenna. Antenna arrays.			
Textbooks/references				
1	D. M. Veličković: Elektromagnetics (in Serbian) - the first book, Faculty of Electronic Engineering, Niš, 2004.			
2	D. M. Veličković and others: The Electromagnetics Problem Solver (in Serbian), Faculty of Electronic Engineering, Niš, 2000.			
3	D. M. Veličković, F. H. Uhlmann, K. Brandisky, R. D. Stancheva, H. Brauer: Fundamentals of Modern Electromagnetics for Engineering, TU Ilmenau, Germany, 2005.			
4	J. V. Surutka: Electromagnetics (in Serbian), Građevinska knjiga, Beograd, 1966.			
5	Fawwaz T. Ulaby: Fundamentals Applied Electromagnetics,Pearson, Prentice Hall, New York, ISBN-13: 978-0132139311, 2010.			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures and auditive practice classes. Besides board work, multimedial presentations, photographs and video clips are presented. Obligatory consultations with lecturers help successful course material adoption.			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**	**Points**	
Activity during lectures		**Written exam**		
Exercises	20	**Oral exam**	40	
Colloquia				
Projects	40			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electromagnetic Compatibility		
Lecturer (for lectures)	Cvetković N. Nenad, Perić T. Mirjana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to problems and requirements of electromagnetic compatibility (EMC) and acqiusition of basic knowledge of the design methods for systems, circuits and equipment in accordance with the EMC requirements.		
Course outcomes	Acquired basic knowledge in the field of EMC, the ability to assess and address EMC issues and practical application in the design of systems and devices.		
Course outline			
Theoretical teaching	Natural and artificial sources of electromagnetic interference. Definitions of EMC, EMI, EMD, EMS. Requirements, regulations and standards in different fields. Limitations and advantages of EMC requirements. Design of circuits and devices in accordance with the EMC requirements. Radiated emissions and conducted emissions. The principles and techniques of design. Selection of configurations and components. Separation, shielding, grounding, filtering. Cables, connectors, contact protection. Protective chokes to limit the current and to reduce the harmonics in order to improve power quality. Electrostatic discharge (ESD) and practical ways of solving problems. Disturbances in power systems and EMC requirements.		
Practical teaching (exercises, OFE, study and research	Practical demonstration of the interference in electric circuits by means of electromagnetic fields and conductive paths.		
Textbooks/references			
1	Williams T., Armstrong K., "Electromagnetic compatibility for systems and installations," Newnes, 2000.		
2	Lattarulo F., "Electromagnetic compatibility in power systems," Elsevier, 2007.		
3	Ott H. W., "Electromagnetic Compatibility Engineering," John Wiley & Sons, 2009.		
4	Paul C. R., "Introduction to electromagnetic compatibility," John Wiley & Sons, 2006.		
5	Poljak D., "Advanced Modeling in Computational Electromagnetic Compatibility", Wiley & Sons, 2007.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations and research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Static Electricity		
Lecturer (for lectures)	Cvetković Ž. Zlata		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the problems of static electricity in technological processes, ways of eliminating static electricity and protection techniques.		
Course outcomes	Acquired basic knowledge about static electricity in technological processes, the ability to assess and address various problems in industry and to use techniques of eliminating static electricity and protection measures.		
Course outline			
Theoretical teaching	Phenomenon of static electricity in technological processes. Theory of ignition of flammable mixtures. Theory of static electricity discharges from conducting and dielectric surfaces. High voltage generation. Modeling of industrial and electrostatic filters. Dangers from static electricity during transportation and storage of flammable and explosive materials. Techniques for measuring electrostatic charges, fields and potentials. Protection measures and elimination of static electricity in technological processes.		
Practical teaching (exercises, OFE, study and research	Reference collecting. Study the selected chapters. Analysis of real problems. Independent research work.		
Textbooks/references			
1	Lüttgens G., Wilson N. "Electrostatic Hazards," Oxford: Butterworth – Heinemann, 1997.		
2	Taylor D. M., Secker P. E. "Industrial Electrostatics: fundamentals and measurements," J. Wiley, Research Studies Press: New York, 1994.		
3	Britton L. G. "Avoiding Static Ignition Hazards in Chemical Operations," American Institute of Chemical□ Engineers, New York, 1999.		
4	Leonard J. T. "Generation of Electrostatic Charge in Fuel Handling Systems: A Literature Survey," NRL Report 8484, Naval Research Laboratory, Washington DC, 1981.		
5	Technical norms guidelines for static electricity protection (in Serbian), Službeni Glasnik, No. 62, 1973.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations, research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Methods for Steady-state Electromagnetic Fields Calculation		
Lecturer (for lectures)	Cvetković N. Nenad, Perić T. Mirjana, Vučković N. Ana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The aim of the subject is to upgrade the student's knowledge of methods for steady-state electromagnetic field calculation. Also, students are capable to implement those methods in their own software tools for solving electromagnetic field problems as well as to use commercial software for electromagnetic fields analysis.		
Course outcomes	Students are capable to use appropriate analytical and numerical methods to perform the characterization of the steady-state electromagnetic field within the researched systems, to analyze the obtained results and make appropriate conclusions.		
Course outline			
Theoretical teaching	Electromagnetic field theory. Electromagnetic problems classification in terms of time dependence. Equations of the steady-state electromagnetic field. Analytical methods (image theorem, method of separation of variables, conformal mapping). Approximate and numerical methods (estimation method, Howe's method, finite difference method, finite element method, boundary element method, method of fictitious sources, equivalent electrodes method). Development and application of own software tools and application of commercial software for the electromagnetic field analysis.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. M. Veličković, Electromagnetics - the first book (in Serbian), Faculty of Electronic Engineering, Niš, 1994, 1999 and 2003.		
2	D. Veličković, „Electrostatic fields calculation mehthods“ (in Serbian), Stil, Podvis, 1982.		
3	B. Popović, Electromagnetics, Belgrade: Akademska misao, 2004.□		
4	D. M. Veličković et al., Collection of solved examples from Electromagnetics - I part (in Serbian), Faculty of Electronic Engineering of Niš, Niš, 2000.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, discussions, scientific work			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program			Electrical Engineering and Computer Science	
Module			Common	
Type and level of studies			Doctoral studies	
The name of the course			Inverse problems in Electromagnetics	
Lecturer (for lectures)			Raičević B. Nebojša, Perić T. Mirjana	
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**		Elective
Prerequisites	None			
Course objectives	The aim of the subject is to acquire the knowledge of solving inverse problems and their practical applications, as well as to learn modern optimization techniques in electromagnetics.			
Course outcomes	Student practically applies optimization algorithms in scientific and research work solving engineering problems. Active use of scientific sources, data processing and writing of papers in the field of doctoral studies.			
Course outline				
Theoretical teaching	• Introduction: Electromagnetic field theory. Static, stationary and dynamic EM fields. Mathematical terms: Jacobi matrix, Hessian matrix, local and global extrema of functions. Direct and inverse problems. The term of objective function. • Establishing the main concepts in inverse problem formulation: defining a task, setting a mathematical model of a physical problem, defining an objective function and boundaries, selecting the optimization method, implementing an algorithm, analyzing the obtained solution, correcting, testing and applying the optimal solution. • Classification of optimization methods. Deterministic methods: Simplex method, Gradient descent algorithm, Newton's method. Variable metric methods: Gauss-Newton and Levenberg-Marquardt algorithms. • Stochastic methods. Evolutionary algorithms: Genetic Algorithm and Evolutionary Strategies. Hierarchical Evolutionary Strategies. Swarm Intelligence Optimization: Particle Swarm Optimization and Ant Colony Optimization. • Multi-criteria optimization. The concept of Pareto optimum. • Application of optimization algorithms to the test functions: Rosenbrock and Rastrigin. Comparison of the methods with respect to the computation time and the parameter variation effects on the optimization results. Inverse problems solving in applied electromagnetics (contactless material testing, electrocardiography, radars, magnetic resonance tomography, etc.). Publishing results in a leading journal.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	Albert Tarantola, „Inverse problem theory and methods for model parameter estimation“, Society for Industrial and Applied Mathematics – SIAM, 2005.			
2	N. V. Korovkin, V. L. Chechurin, M. Hayakawa, „Inverse problems in electric circuits and electromagnetics“, Springer, 2007.			
3	Z. Michalewicz, „Genetic Algorithms + Data Structures = Evolution Programs“, 3rd edition, Springer, 1995.			
4	David E. Goldbreg, „Genetic algorthms in search, optimization and machine learning“, Addison-Wesley Publishing Company. Inc., 1989.			
5	Z. Michalewicz, D.B. Fogel, „How to Solve It: Modern Heuristics“, Springer; 2nd edition, 2004.			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	PPT presentations, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	40
Colloquia			
Projects	60		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Bounday Element Method in Electromagnetics		
Lecturer (for lectures)	Raičević B. Nebojša, Vučković N. Ana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	None		
Course objectives	The aim of the subject is to acquaint the student in detail with the fundamentals of electromagnetic field analysis using boundary elements method and hybrid boundary element method. Also, the student learns to apply some of the leading software for modeling and analyzing practical problems in the Electromagnetics.		
Course outcomes	The student is capable to analyze the electromagnetic systems using boundary elements method and hybrid boundary element method and to present the obtained results.		
Course outline			
Theoretical teaching	• Numerical methods in Electromagnetics – introduction. • Boundary element method (integral equations formulation, boundary elements discretization, sources modeling within the analysis domain, linear and square elements). Examples. • Hybrid boundary element method (theoretical background, system modeling, 2D and 3D problems analysis). Examples. • Modern software for electromagnetic fields analysis.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Matthew Sadiku, „Numerical techniques in Electromagnetics“, CRC Press, 2001.		
2	Dragan Poljak, C. A. Brebbia, "Boundary Element Methods for Electrical Engineers", WIT Press, 2005.		
3	C. A. Brebbia, J. Dominguej, "Boundary Element Methods, An Introduction Course", McGraw Hill, 1989.		
4	Dragan Poljak, “Advanced Modeling in Computational Electromagnetic Compatibility”, Wiley & Sons, 2007.		
5	Nebojsa B. Raicevic, Slavoljub R. Aleksic, "One method for electric field determination in the vicinity of infinitely thin electrode shells", Engineering Analysis with Boundary Elements, ELSEVIER, Vol. 34, Issue (No.) 2, pp. 97-104, 2010		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures and auditory classes. Besides boardwork, multimedia presentations, photographs and video clips are presented. Obligatory consultations with lecturers help successful course material adoption.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	20
Exercises		**Oral exam**	20
Colloquia			
Projects	60		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Metrology of Electrical Quantities		
Lecturer (for lectures)	Denić B. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	No		
Course objectives	Foundation of knowledge from theoretical, legislative and applied metrology and development of capability for critical scientific approach in research and development of project tasks from area related to the metrological assurance of electrical and electronic products quality, capability for tracking the modern literature in these areas and for presentation of technical ideas and innovations to the scientific public.		
Course outcomes	Complete understanding of scientific methods in development and presentation of new solutions and contribution in development of materialisation and reproduction of measures and measurement methods, with achieved results in the scientific and professional public by means of published papers.		
Course outline			
Theoretical teaching	Measurement and metrology. Development of measurement units system. Physical constants. National and international metrological institutions. Measurement and measuring methods. Analysis of sources for errors and interferences in measurement. Metrological characteristics of measuring resources. Calibration and comparison of measurement standards - traceability. Methods for processing of measurement results and determination of measurement uncertainty. Using of computer components in metrology for gathering, processing and communication of measurement and information data.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	P. Pravica, I. Bagarić, “Metrology of Electrical Quantities - General Part“ (in Serbian), Nauka, Belgrade.		
2	S. Tumanski, “Principles of Electrical Measurements”, Taylor & Francis Group, 2006.		
3	P. Sydenham, “Handbook of Measurement Science“, John Wiley & Sons, Ltd.		
4	International professional journals: Metrology, Instrumentation and Measurement, Measurement Science and Technology, Measurement Science Review, etc.		
5	Professional publications of international metrological organizations and institutions.		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Systematization of relevant publications, analysis of selected chapters, making of seminar paper, participation in realization of project tasks and preparation of scientific papers for publication at conferences and journals.

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	0	**Written exam**	30
Exercises	0	**Oral exam**	30
Colloquia	0		
Projects	40		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Sensors and Measurement Transducers		
Lecturer (for lectures)	Denić B. Dragan, Radenković N. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquisition of basic knowledge in the field of sensors and transducers and different types of their applications. The goal is also to familiarize students with the principles of measurement of non-electrical quantities and sensor systems used in modern measurement systems.		
Course outcomes	Student's ability to understand basic principles of work of a large number of sensors and transducers. Ability to select the sensor and measuring method in individual practical examples.		
Course outline			
Theoretical teaching	Basic block diagram of transducers. Basic definitions. Sensor as the basic element of the transducers. Information-energy parameters of transducers. Trends in the development of sensors and transducers. Active and passive transducers. Analog and digital transducers. Integrated, intelligent sensors and measurement modules. Transducers of temperature, force, pressure, flow, level, displacement, humidity. Analog electronic circuits for sensor connections.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. Stanković, „Physical-technical measurements - sensors“, University of Belgrade, 1997 (in Serbian).		
2	J.Webster, “The measurement, instrumentation, and sensors handbook”, CRC Press, 1999.		
3	W. Nawrocki, „Measurement systems and sensors“, Artech House, 2005.		
4	J. Fraden, „Handbook of modern sensors, physics, designs and applications“, Springer, 2004.		
5	I. Sinclair, „Sensors and transducers“, third edition, Newnes, 2001.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures and laboratory work within the framework of research work. The first steps in scientific research are expected in certain areas within defined project tasks; students will be involved in the process of writing and presenting scientific papers.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Systems for Measurement and Control		
Lecturer (for lectures)		Dinčić R. Milan		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Systematization of knowledge in the field of electronic measurements and control systems as well as studying modern measurement systems.			
Course outcomes	Increasing the level of knowledge, gaining insight into the achievements of science and technology in measurement systems, the ability to design measurement systems.			
Course outline				
Theoretical teaching	Information theory of measuring signals. Measurement errors. Measurement and control systems. Metrological system. Analog and digital signal processing systems. Design of automated measurement and control systems. System engineering. Management and evaluation of the system. Intelligent and virtual instrumentation. Embeded systems and systems for diagnostics. Reliability.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	P.H.Sydenham et al., “Measurement Science and Engineering“, John Wiley and Sons.			
2	J.Webster, “The measurement, instrumentation, and sensors handbook”, CRC Press, 2014.			
3	C.F.Coombs ed, “Electronic instrument handbook“, McGraw-Hill, 2000.			
4	D. Stanković „Physical-Technical Measurements - Sensors“, University of Belgrade, 1997 (in Serbian).			
5				
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Laboratory work within the framework of research tasks. The first steps in scientific research are expected in certain areas within defined project tasks; students will be involved in the process of writing and presenting scientific papers.			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**	**Points**	
Activity during lectures		**Written exam**		
Exercises		**Oral exam**	50	
Colloquia				
Projects	50			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Virtual Instrumentation		
Lecturer (for lectures)	Živanović B. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Studying of performances of information technology components applied in measuring and information systems and introduction with techniques for simulation of measurement methods and processing of measurement results by using of virtual instrumentation.		
Course outcomes	Fully mastery of scientific methods in development and presentation of new solutions and contribution in development of virtual instrumentation software for measuring and information applications.		
Course outline			
Theoretical teaching	Contemporary model of measuring instrument. Standard architectures of computer measuring instrumentation. Software as measuring instrument. Graphical user interfaces. Organization of software tool LabVIEW. Programming structure and functions of virtual instrument. Development of virtual instrument for gathering of measuring and information data and statistical processing of measurement results. Control of programmable instrumentation. Examples for practical applications of virtual instrumentation in measuring systems for real-time work.		
Practical teaching (exercises, OFE, study and research	Practical development of Virtual instrument		
Textbooks/references			
1	N. Kularatna, " Digital and Analogue Instrumentation testing and measurement", The Institution of Engineering and Technology, London.		
2	J.Y. Beyon, “LabVIEW Programming, Data Acquisition and Analysis“, Prentice Hall.		
3	J. Conway, “A Software Engineering Approach to LabVIEW “, Prentice Hall.		
4	S. Tumanski „ Pricniples of Electrical Measurement“, Taylor&Francis		
5	Burns, M.,Roberts,G.W.,"Mixed-Signal IC Test and Measurement",Oxford Univ. Press,New York		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Systematization of relevant publications, analysis of selected chapters, making of seminar paper, participation in realization of project tasks and preparation of papers for publication at conferences and journals.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	50	**Oral exam**	50
Colloquia			
Projects			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Process Measurement Technique		
Lecturer (for lectures)	Jovanović R. Jelena		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Systematization of knowledge of measurement techniques in process industry and of technical systems.		
Course outcomes	Ability to design instrumentation for measurement, control and monitoring of the technical system.		
Course outline			
Theoretical teaching	Basic principles of measurement systems and measurement techniques in the process industry. Measurement transducers and systems. Mechatronic systems. Measurement of dimensions, linear and angular position. Measurement of force and moment. Measurement of number of rotations and angular speed. Measurement of vibration and impacts. Temperature measurement and thermovision. Measurement of pressure, differential pressure and vacuum. Flow measurement. Level measurement. Measurement of humidity. Measurement-informational systems. Programmable industrial automation systems. The basic principles of the application of the Internet of Things technology in monitoring industrial processes and technical systems.		
Practical teaching (exercises, OFE, study and research	The basic principles of the application of the Internet of Things technology in monitoring industrial processes and technical systems by using open-source platforms, such as Arduino and Raspberry Pi.		
Textbooks/references			
1	P.H.Sydenham et al., “Measurement Science and Engineering“, John Wiley and Sons.		
2	J.Webster, “The measurement, instrumentation, and sensors handbook”, IEEE Press, 1999.		
3	C.F.Coombs ed, “Electronic instrument handbook“, McGraw-Hill, 2000.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Lectures and laboratory work within the framework of research work. From certain areas within defined project tasks, the first steps in scientific research are expected, and students are involved in the process of writing and presenting of scientific papers.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	50
Exercises		**Oral exam**	
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Measurement and Acquisition Systems		
Lecturer (for lectures)	Denić B. Dragan, Živanović B. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Establishment of knowledge necessary for the development and application of measurement and acquisition systems based on information technologies and microcomputer components		
Course outcomes	Mastering the scientific methods in the development and presentation of new DAQ cards solutions in the development of computer-based measurement systems for the acquisition, processing and display of measurement results in centralized and distributed measurement systems.		
Course outline			
Theoretical teaching	Physical and mathematical models of measurement process. Conversion methods of processed signals (ADC and DAC). Signal conditioning (linearization, amplification, filtering, etc.). Acquisition of measurement data (multiplexing, S & H circuits, converters). Universal Acquisition Card. Standard interfaces and communication protocols in acquisition modules. Automatic test systems based on DAQ with applications.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	S. Tumanski, “Principles of Electrical Measurement, Chapter 6. Computer Mesuring Systems“, CRC Press.		
2	A. Robert, “Witte Electronic Test Instruments: Theory and Applications“, PTR Prentice Hall.		
3	E. Doebelin, “Measurement Systems. Application and Design“, McGraw-Hill.		
4	J. Park, S. Mackay, “Practical data acquisition for instrumentation and control systems“, Elsevier.		
5	W. Nawrocki, “Measurement systems and sensors“, Artech House.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Systematization of relevant publications, analysis of selected chapters, realization of seminar tasks, participation in realization of research project tasks and preparation of papers for publication in conferences and journals.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Industrial Measurement and Information Systems		
Lecturer (for lectures)	Denić B. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The objective of the course is to introduce a student with modern industrial measurement and information systems, with theoretical and practical knowledge required to analyze and design such systems. The objective of the course is also to train students for scientific research in this field.		
Course outcomes	Ability to demonstrate knowledge and understanding of the operating principles of industrial measurement systems based on application of the computer, ability to analyze and select appropriate hardware and software. Ability to design and realize some examples of virtual instruments.		
Course outline			
Theoretical teaching	Basic block diagram of measurement-information system. Definitions. Signal Processing and Signal Transmission. Wired and wireless telemetry. Standards. Design of analog electronic circuits for sensors connection. Methods and systems for improving the signal-to-noise ratio. Computer-based systems and standard communication interfaces. Distributed measurement systems and Internet connectivity. Virtual instrumentation and virtual laboratories.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. Denić, I. Ranđelović, D. Živanović „Computer-based measurement systems in industry“, Faculty of Electronic Engineering Niš and WUS Austria, script, 2005 (in Serbian).		
2	R. Zurawski, “Industrial information technology handbook”, CRC Press, 2005.		
3	R. Zurawski, “Industrial communication technology handbook”, CRC Press, 2005.		
4	W. Nawrocki, „Measurement systems and sensors“, Artech House, 2005.		
5	S. Sumathi, P.Surekha, “LabVIEW based advanced instrumentation systems”, Springer, 2007.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures and laboratory work within the framework of research tasks. The first steps in scientific research are expected in certain areas within defined project tasks; students will be involved in the process of writing and presenting scientific papers.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Measurement and Information Technologies		
Lecturer (for lectures)	Denić B. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering the general hardware-software structure of the measurement-information systems, as well as individual blocks. Understanding the influence of applied techniques on the accuracy of measurement.		
Course outcomes	Ability to design individual instruments with the application of measurement-information technologies, as well as the system as a whole. Ability to understand user requirements, select components, design individual circuits, and analyze the achieved metrological parameters.		
Course outline			
Theoretical teaching	General models of the measurement process. Sources of measurement data and metrological parameters of measurement signals. Microelectronic circuits for the processing of measurement signals. Components for analog-digital conversion of measurement signals (multiplexers, semplers, ADC, DACs) and indicators. Architecture and hierarchical organization of software for measurement systems. Universal acquisition cards. Measurement-information electronic modules (DAQ, DAS). Standard interfaces. Intelligent and virtual measurement instruments. Principles of calibration of measurement modules and systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Burns, M., Roberts, G.W.,"Mixed-Signal IC Test and Measurement",Oxford Univ. Press, New York, 2001.		
2	Barney, G.C., “Intelligent Instrumentation”, Prentice Hall, New York, 1998.		
3	National Insturments, "Measurement and Automation Catalog", National Instruments Catalog.		
4	Horn, G., Huijising, J., "Integrated smart sensors, design and calibration", doctoral diss., Delft, Kluwer Academic Publisher, Netherlands, 1998.		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures with the use of modern presentation tools. Work in the laboratory within the framework of the research tasks. Working on defined project tasks. Inclusion in the process of writing and presenting scientific papers.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Medical and Bioelectronic Measurement Technique		
Lecturer (for lectures)	Simić M. Milan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	No		
Course objectives	Systematization and acquiring of knowledge from the field of medical and bioelectronic measurement technique.		
Course outcomes	Students ability to design medical and bioelectrical measurement instrumentation, as for practical application of this specific measurement devices.		
Course outline			
Theoretical teaching	Introduction to biomedical measurement instrumentation. Sources of bioelectric potentials. Biopotential amplifiers and signal processing. Electrostimulation. ECG, EEG, EMG, ERG. Ultrasonic medical devices. Electrotherapy. Defibrillators. Pacemakers. Surgical instrumentation. Instruments for the making of medical images based on electromagnetic radiation and on the basis of nuclear magnetic resonance.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	David Prutchi, Micahel Norris, “Design and Development of Medical Electronic Instrumentation”, JOHN WILEY & SONS, New Jersey, 2005.		
2	Joseph Carr, John Brown, “Introduction to Biomedical Equipment Technology”, Third Edition, PRENTICE HALL, New Jersey, 1998.		
3	D.Jennings, A.Flint, B.C.H.Turton and L.D.M.Nokes, “Introduction to Medical Electronics Application”, EDWARD ARNOLD, London, 1995.		
4	John G. Webster, “Medical Instrumentation Application and Design, Second Edition”, JOHN WILEY & SONS, 1995.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Systematization of relevant publications in this field, analysis of selected chapters, making of seminar paper and participation in realization of project tasks. In specific areas within the defined project tasks students should take part in the process of preparing research papers for publishing in the conferences and journals.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	0	**Written exam**	30
Exercises	0	**Oral exam**	30
Colloquia	0		
Projects	40		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Semiconductor Physics		
Lecturer (for lectures)	Prijić P. Aneta		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Objectives of the course are focused on: - Refining knowledge in the field of crystal structure and quantum solid state physics; - Detailed analysis of the transport of carriers through semiconductors; - Consideration of non-equilibrium phenomena in the P-N and the metal-semiconductor junction; - Introduction to the charge sheet model of MOS structures; - Detailed analysis of C-V plots of MOS capacitors; - Study of the effects characteristic for the MOS transistors at a level of very large scale integration; - Getting acquainted with structures based on heterojunctions and semiconductor compounds; - In-depth consideration of the functioning of optoelectronic devices.		
Course outcomes	Learning outcomes allow a student to: - Explain the zonal theory in crystals from the aspect of the quantum-mechanical theory of a solid state; - Compare the classical relations for the transport of charge carriers in a semiconductor with particular solutions of the Boltzmann's kinetic equation; - Explain in detail the generation-recombination and diffusion processes in the semiconductors; - Highlight the specificity of the metal-semiconductor junction and heterojunction; - Present the charge sheet model of MOS structures: - Determine the characteristics of the specified MOS capacitor on the basis of its C-V plot; - Analyze the effects of MOS transistors scaling at a level of very large scale integration; - Explain in-depth the functioning of optoelectronic devices.		
Course outline			
Theoretical teaching	Crystal structure and solid state theory. Quantum and statistical physics of a solid state. Boltzmann's kinetic equation. Semiconductor in thermal equilibrium. Excess carrier concentrations and transport of carriers. Generation-recombination mechanisms. Metal-semiconductor junction and P-N junction. Non-equilibrium phenomena in the P-N junction and transport equations. Models of carriers mobility. MOS structure. Charge sheet model and C-V plot. MOS transistors and short channel effects. Parasitic effects, hot carriers, high temperature effects. Bipolar devices. SiGe, HEMT and other heterojunction devices. Solar cells, photodetectors, LEDs and laser diodes.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	S. Sze, K. Ng, "Physics of Semiconductor Devices", 3rd Edition, Wiley-Interscience, 2007 - selected chapters.		
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Consulting teaching; Participation in the realization of scientific-research projects; Inclusion in the teaching process at bachelor and master academic studies; Seminars and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	30	**Oral exam**	40
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Microelectronics		
Lecturer (for lectures)	Prijić D. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The objectives of the course are such that the PhD student will: - Learn in detail about certain types of analog microelectronic circuits and their models; - Learn about certain types of digital microelectronic circuits and their models; - Be able to analyze and design electronic products that contain analog and digital microelectronic circuits.		
Course outcomes	Learning outcomes are defined so that a PhD student will: - Distinguish the areas of application of certain types of analog microelectronic circuits and describe their functioning, using the model of the appropriate level of complexity; - Distinguish the areas of application of certain types of digital microelectronic circuits and describe their functioning, using the model of the appropriate level of complexity; - Design an electronic product that contains analogue and digital microelectronic circuits, according to the given functional and technical specifications.		
Course outline			
Theoretical teaching	Analog microelectronic circuits in practice: General principles of design of analogue microelectronic circuits; Power supply in integrated circuits and active load; Design of circuits with operational amplifiers (CMOS, bipolar, BiCMOS, JFET); Differential and multistage amplifiers; Feedback and stability; The effects of nonideality; Active higher order filters; Oscillators and function generators; A / D converters. Digital microelectronic circuits in practice: Digital circuits in MOS technology; Sequential logic circuits; MOS memory, SRAM, DRAM, Flash; Data converters. Optional: Digital circuits in bipolar technology. ECL and modified ECL circuits. TTL circuits. Logical circuits with Schottky diodes. Digital circuits in BiCMOS technology.		
Practical teaching (exercises, OFE, study and research	Study research work in the field of analogue or digital microelectronic circuits, according to student affinity.		
Textbooks/references			
1	A. Hastings, „The Art of Analog Layout“, 2nd Ed., Pearson Education, 2006.		
2	R. Jaeger, T. Blalock, „Microelectronic Circuit Design”, 5th. Edition, McGraw-Hill, 2016.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Lectures; Consultations. Active participation in scientific and research projects.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Nanotechnology and Nanodevices		
Lecturer (for lectures)	Pantić S. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Gaining higher level of knowledge in the field of nanotechnology and nanocomponents.		
Course outcomes	Extended theoretical knowledge in the field of nanotechnology and nanocomponents, as well as the application of systems based on these components. The student should understand the basic principles and accept new knowledge.		
Course outline			
Theoretical teaching	Materials for nanodevices. Dielectric and ferroelectric materials (electronic properties and quantum effects), magnetic materials (magnetism and magnetotransport in layered structures), organic molecules (electronic structures, properties and reactions), neurons (molecular basis of their electrical excitability). Technological processes and analyzing methods. Nanostructure characterization. Geometric characterization. Surfaces and layers characterization. Functional characterization. Nanosensors and nanoactuators. Nanodevices. Contacts, quantum dots, nanodiodes, nanotranzistors, nanoswitches. Nanooptical devices. Logic nanodevices and RAMs. Mass storage devices. Nanosystems and their application.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Rainer Waser (Ed.), Nanoelectronics and Information Technology, Wiley-VCH, 2003.		
2	L.E. Foster, G. Allen, Nanotechnology: Science, Innovation, and Opportunity, Prentice Hall Professional Technical Reference, 2005.		
3	D.B. Baird, A. Nordmann, J. Schummer, Discovering the Nanoscale, IOS Press, 2004.		
4	M. Kohler, W. Fritzsche, An Introduction to Nanostructuring Techniques, 2005.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures in the form of the Power Point presentations, including of students in realizations of Scientific-Research projects and BSc and MSc study assistance, seminar works.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Materials Science		
Lecturer (for lectures)	Mitić V. Vojislav		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective

Prerequisites	
Course objectives	The subject offers academic knowledge on materials science and enables to interlink knowledge from different areas of research. It offers an insight into the most recent achievments in the research and application of advanced materials. It also focuses on the study of the structure-properties-application relationship.
Course outcomes	Students develop the capacity to deal with scientific, development an technological problems either alone or as members of a team, as well as to organize and implement scientific research. They should also be able to take part in international research projects owing to the experience gained through the research during studies.
Course outline	
Theoretical teaching	Matter and materials. Materials science as an international priority issue. Materials science and engineering. The synthesis (technology) – structure – properties – materials application correlation. Materials-energy-information. Structural properties of materials. Structural hierarchy of materials and symmetry. Crystallography. Modern materials characterization methods (SEM, TEM, EDS, XRD, laser and NMR spectroscopy). Stereological methods (quantitative metallography). Fractals theory as a link between the order and chaos in the material world. Application of fractals in the structural analysis and properties' simulation and materials synthesis technology. Inter-atomic links. Energy and crystal lattices. Crystal defects. Modelling and simulation of novel structures and properties of materials. Phase diagrams and designing of novel materials with controlled properties. Models of the electronic structure of materials. Electric conductivity in metals. Semiconducting materials and their properties. Quantum gaps. Optical properties of semiconductors. The age of electronic ceramic materials. Advanced oxide and non-oxide materials. Liquid crystals. Ferroelectrics. Ferrites and other materials with magnetic properties. Nanopowders, nanomaterials and nanotechnology of the synthesis of advanced materials. Role of materials structure in the high integration of electronic components and electronic parameters in microelectronic devices. Globalization and strategy of research and development of new materials and technologies in the world.□ □
Practical teaching (exercises, OFE, study and research	Part of the exercises and lectures are performed at institutes, laboratories, companies and the Center for Electronic Microscopy.
Textbooks/references	
1	Vojislav V. Mitić, Momčilo M. Ristić, Electrical materials, (in the process of publishing, in Serbian)
2	Vojislav V. Mitić, Materials for new and alternative energy sources, (in the process of issuing publishing, in Serbian)
3	Vojislav V. Mitić, Structure and electrical properties of BaTiO3 ceramics, Belgrade, Endowment Andrejević, 2001. (in Serbian)
4	D.Raković, Physical basics and characteristics of electrical materials, Belgrade, (1997) (in Serbian)
5	W.D.Callister, “Materials Science And Engineering an introduction, John Wiley&Sons Ltd, 2003

Number of classes of active education per week during semester/trimester/year

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0

Teaching methods	Lectures and consultations. For the theoretical part of the curriculum that includes a seminar paper, the research is conducted inuniversity laboratories, institutes and factories.

Grade (maximum number of points 100)

Pre-exam duties	Points	Final exam	Points
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Optoelectronics		
Lecturer (for lectures)	Paunović V. Vesna		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the light properties, light sources and detectors, and optoelectronic circuits and systems.		
Course outcomes	Expanded knowledge in the field of optics and radiation physics. Practical mastery of optoelectronic techniques and technologies of optoelectronic devices and systems. Detailed knowledge of laser devices and systems. Use of lasers and their control in various systems. Making projects.		
Course outline			
Theoretical teaching	Optoelectronics as experimental science, i.e. scientific cycle of theory and experiment, and its multidisciplinary in the viewpoint literature and internet technology, as the basis of study of light and matter. Optics, electrodynamics, electronics, quantum and statistical physics of radiation. Source of light and components of telecommunication devices and systems. Interaction of radiation and matter. Laser light sources. Semiconductor lasers. Some telecommunication laser systems. Information displays, cathode ray, LC, TFT and perspective of development of display technology. Discrete and integrated optoelectronic components and devices. Integrated and quantum optoelectronics. Optical, electro optical and quantum-electrodynamical effects in the optical circuits and devices. Propagation of electromagnetic waves in anisotropic crystals. Integrated optical systems for propagation, modulation, oscillation and switch of light in optical dielectric materials. Optoelectronic materials and technologies. Limits and perspective of development of optoelectronics.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	B. Naci, E. Ayse, Semiconductors for Optoelectronics : Basics and Applications, Springer International Publishing, 2019		
2	S.C.Gupta, Optoelectronic devices and systems , Prentice Hall of India Private, 2015		
3	Chartier, G.; Introduction to Optics, Springer, 2005.		
4	Anil K. Maini Lasers and Optoelectronics, John Wiley and Sons Ltd, 2013		
5	Wenping Hu, Organic Optoelectronics, Wiley VCH , 2013		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Theoretical lectures, consultations, participation in realization of scientific-research projects, seminar papers and projects.

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Semiconductor Devices		
Lecturer (for lectures)	Danković M. Danijel		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Detailed analysis of physical phenomena in semiconductors and semiconductor devices. Study of the specific applications of semiconductor devices in electronic circuits.		
Course outcomes	Detailed knowledge of the semiconductor devices and their applications in the electronic circuits.		
Course outline			
Theoretical teaching	Heavy Doping Effects in Semiconductors. Transport of Carriers. l-h junctions. The effective surface recombination velocity. Diode. Silicon Bipolar Junction Transistors. Heterojunction Bipolar Transistors. Modeling of Bipolar Junction Transistors. Metal-Semiconductor based Devices. Schottky Barriers and Ohmic Contacts. Field Effect Transistors based on Semiconductor Compounds. GaAs MESFET's. Heterostructure Field Effect Transistors (HFETs). MOSFETs. CMOS/BiCMOS. SOI and 3D structures. Low-voltage and Low-power Devices. Power Devices. Power Bipolar Junction Transistors. Power VDMOS transistors. IGBT. Devices Based on SiC.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	James M. Fiore, "Semiconductor Devices: Theory and Application", Mohawk Valley Community College-Utica, 2019.		
2	Donald A. Neamen, "Semiconductor Physics and Devices: Basic Principles", 4th Edition, McGraw-Hill, 2011, ISBN 978-0-07-352958-5.		
3	Umesh K. Mishra, Jasprit Singh, "Semiconductor Device Physics", Springer, 2008, ISBN 978-1-4020-6481-4.		
4	Simon M. Zee, Ming-Kwei Lee, "Semiconductor Devices - Physics and Technology", 3rd Edition, John Wiley & Sons, 2012.		
5	Simon M. Zee, Kwok K. Ng, "Physics of Semiconductor Devices", 3rd Edition, Wiley Interscience, 2007, ISBN 978-0-471-14323-9		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Theoretical teaching, active role in the scientific-research projects, seminars and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Power Devices and Circuits		
Lecturer (for lectures)	Manić Đ. Ivica		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	To acquire detailed knowledge on the structure, technology, principles of operation, characteristics and applications of specific power semiconductor devices and integrated circuits		
Course outcomes	Theoretical and practical knowledge for understanding of power device functions in the circuit and proper choice of power devices for given applications and reliable operation of electronic circuits		
Course outline			
Theoretical teaching	Introduction. Types and applications of power devices. Structures and technologies: bipolar, CMOS, BiCMOS, SOI. Discrete power devices. PN, PiN and Schottky diodes. Thyristors: SCR, GTO, triac, optically triggered thyristor. Bipolar Transistors. Darlington couple. Static induction power devices: SIT and SITh. MOS power devices: LDMOS and VDMOS transistors, MOS controlled thyristor. IGBT. Electrical characteristics and special effects. High current density effects, quasi-saturation, on-resistance, thermal effects, secondary breakdown, the effects of parasitic elements. Safe operating area (SOA). Electrical SPICE models. Power integrated circuits. Principles of integration of power devices, power modules and hybrid ICs. Monolithic power ICs: high-voltage ICs, smart power ICs and system-on-chip (SoC), isolation of devices on a chip. Functional blocks of smart power ICs. Driving circuits. Voltage references. Circuit for external communication. Protection blocks: over-voltage, over-current and temperature protection. Smart power application examples: smart power in automotive electronics, lighting control, electric motor operation control.		
Practical teaching (exercises, OFE, study and research	Study-research work includes individual theoretical and practical investigations of particular issues related to the design, technology, application and reliability of specific power devices		
Textbooks/references			
1	V. Benda, J. Gowar, D.A. Grant, Power Semiconductor Devices – Theory and Applications, John Wiley & Sons, Chichester (UK), 1999, ISBN 0-471-97644-X		
2	B. Jayant Baliga, Modern Power Devices, John Wiley & Sons, New York, 1987 ISBN 0-471-81986-7		
3	B. Murari, F. Bertotti, G.A. Vignola, Smart Power ICs (2nd ed.), Springer, Berlin, 2002, ISBN 3-540-43238-8		
4	M. H. Rashid (Editor), Power Electronics Handbook, Academic Press, San Diego, 2001, ISBN 0-12-581650-2		
5	J. Lutz, H. Schlangenotto, U. Scheuermann, R. De Doncker, Semiconductor Power Devices: Physics, Characteristics, Reliability (2nd ed.), Springer, 2018, ISBN 978-3-319-70916-1		

Number of classes of active education per week during semester/trimester/year

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0

Teaching methods	Lectures, study-research work, consultations

Grade (maximum number of points 100)

Pre-exam duties	Points	Final exam	Points
Activity during lectures	10	Written exam	
Exercises	30	Oral exam	40
Colloquia			
Projects	20		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Microsensors		
Lecturer (for lectures)		Vračar M. Ljubomir		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Acquiring a higher-level knowledge for understanding and practical application of microsensors and microsystems.			
Course outcomes	Students obtain a detailed knowledge of the fabrication, operational principles and practical implementation of modern microsensors and microsystems.			
Course outline				
Theoretical teaching	Information-processing systems. Measurement and control systems. Actuators. Sensor definitions and classification. General sensor characteristics and limitations. Parameters definition. Sensor calibration methods. Error corrections. Fabrication technology. Reliability issues. Sensors for radiation, mechanical, thermal ,magnetic , chemical and biological signals. Sensors design and operation. Applications. Smart integrated sensors and actuators. Functional blocks. Micro-electro-mechanical sensors (MEMS), technology, components and systems. Integrated sensors and MEMS components.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	J.W. Gardner, Microsensors: Principles and Applications, Wiley, UK, 1994			
2	Gardner J., Varadan V., Awadelkarim O.: Microsensors, MEMS and smart devices: technology, applications & devices , Wiley, UK (2001)			
3				
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Auditorial teaching, Laboratory exercise, student tutorials			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	10	**Written exam**	
Exercises		**Oral exam**	60
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Reliability of Electronic Devices and Microsystems		
Lecturer (for lectures)	Davidović S. Vojkan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The objective of the course is to master knowledge in the field of reliability (Reliability function, time to failure, mean time between failures, distribution functions: exponential, Weibull, normal, gamma distribution), mastering knowledge of failure physics and diagnostics of various components that are part of the microsystem (semiconductor devices, printed circuit boards, capacitors, coils, batteries, transmitters-receivers), as well as acquiring the knowledge necessary to form a model of reliability of the microsystems and use of software tools in modeling. Also, the objective of the course is to familiarize with existing standards and laboratory methods for accelerated testing (HALT, HASS, BURN-IN, thermal cycling, vibration), and calculation of the reliability of microsystems based on specific tests performed on individual components.		
Course outcomes	The student has knowledge from the basic theory of reliability, understands the reliability function and failure rate, understands several different distribution functions in that scope so that he can mathematically successfully process them, or perform the necessary calculations. He knows what are the possible forms and causes of failure in the constituent elements of the microsystem, he knows mechanisms and models for accelerating the failure in the operation at elevated temperature, voltage, humidity, radiation, electrostatic discharge, vibration, mechanical and simultaneous stress. He possesses the necessary knowledge of the tests for certain components, the laboratory equipment for their implementation. He is familiar with contemporary scientific achievements in the field and relevant scientific publications. He can form a model of reliability of the microsystem, to use software tools, and to perform reliability calculations.		
Course outline			
Theoretical teaching	Elements of reliability theory. Failure, mechanisms, and cause of failure. Reliability function, failure rate, bathtub curve, mean time to failure, mean time between failures, distribution functions (exponential, Weibull, normal, gamma distribution). Degradation and failure of microelectronic devices (defects in the substrate, defects in oxide, breakdown of dielectrics, failures at contacts and metallization, case and terminals). Overstress induced failures (elevated temperature, humidity, electric field, ionizing radiation, electrostatic discharge, mechanical stress and vibration). Reliability and failures in multilayer printed circuits boards, capacitors, coils, lithium-ion batteries, transceiver modules, MEMS components, solar modules. Failure diagnostics, microscopy and electrical testing. Accelerated reliability testing - appropriate tests and equipment, acceleration factor for individual tests. MIL-STD and IEC standards. Analysis of the time to failure. Chi-square test. Application of the Weibull + software package for reliability modeling.		
Practical teaching (exercises, OFE, study and research	EXERCISES: Classical tasks based on practical examples, calculation of reliability and hazard function, time to failure. LABORATORY: Accelerated testing of several components (microsystem elements) under harsh conditions (elevated temperature, polarization or radiation). Analysis of results and modeling. CONSULTATIONS: Obtaining results and analysis of relevant scientific publications.		
Textbooks/references			
1	F. Jensen, Electronic Component Reliability, John Wiley, 1995		
2	J. W. McPherson, Reliability Physics and Engineering (Time-To-Failure Modeling), Springer, 2010, ISBN 978-1-4419-6347-5		
3	Elsayed A. Elsayed, Reliability Engineering (2nd edition), John Willey & Sons, 2012, ISBN 978-1-118-13719-2		
4	Lawrence M. Leemis, RELIABILITY - Probabilistic Models and Statistical Methods,(2nd edition), 2009, ISBN 978-0-692-00027-4		
5	Microelectronics Reliability, Elsevier, selection of appropriate scientific papers in the field		
Number of classes of active education per week during semester/trimester/year			

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0
Teaching methods	Lectures, consultations, computational exercises and task processing from practical examples, analysis of presentations and scientific publications, laboratory work, consultations in the form of mentoring in the processing of results.			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures		20	**Written exam**	20
Exercises		20	**Oral exam**	20
Colloquia		10		
Projects		10		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Prognosis of the Material Properties		
Lecturer (for lectures)	Paunović V. Vesna		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Prognosis of the materials properties as the base of developing and producing of materials and nanomaterials.		
Course outcomes	Increased knowledge and practical mastery of the material properties prognosis diagram, starting from the material structure, electronics requirements to the corresponding technology. Adequate theoretical and practical knowledge to predict the structure, properties, and materials technology.		
Course outline			
Theoretical teaching	Prognosis of material properties as a basis for obtaining materials with predetermined properties. Scientific chain of theory-experiment. Multidisciplinary approach to studying prognosis from the point of view of availability of literature and the Internet. Evolution of material structure and nanometerials. Diagram structure-properties-technology from the standpoint of electronic devices and the prognosis of metal, ceramic, amorphous, and other materials. Symmetry in solid state and liquid -crystal materials. Micro and atomic structure of ideal and non-ideal crystalline materials. Electronic structure as the basis for a modern prognosis of material properties. Thermodynamic methods of prognosis. A classical and statistical-thermodynamic approach to the study of thermal, mechanical, electromagnetic, galvanomagnetical and electro-optical phenomens. Properties and technology of materials. The prognosis of the materials properties on the standpoint requires micro, nano, opto and low-temperature electronics. Perspectives of prognosis development with reference to modern technologies.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	S. O. Kasap, Principles of Electronic Materials and Devices, McGraw-Hill, 2017		
2	W.D.Callister, “Materials Science And Engineering an introduction, John Wiley&Sons Ltd, 2003		
3	W. D. Callister, D.G.Rethwisch, Materials Science and Engineering, John Wiley & Sons Inc, 2014		
4	K.M. Gupta Nishu Gupta, Advanced Electrical and Electronics Materials: Processes and Applications, John Wiley & Sons, 2015		
5	Eugene A.Irene, Electronic materials science, John Wiley & Sons, Inc.2005		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Classical lectures, consultations, participation in realization of scientific-research projects, seminar and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Electronic Ceramic Materials		
Lecturer (for lectures)	Mitić V. Vojislav		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The subject offers academic knowledge on electronic ceramic materials and enables to interlink knowledge from different areas of research. It offers an insight into the most recent achievments in the research and application of advanced ceramic materials. It also focuses on the study of the structure-properties-application relationship.		
Course outcomes	Students develop the capacity to deal with scientific, development an technological problems either alone or as members of a team, as well as to organize and implement scientific research. They should also be able to take part in international research projects owing to the experience gained through the research during studies.		
Course outline			
Theoretical teaching	New ceramic civilization. Global strategy of research and development of electronic ceramic materials. Correlation between the structure hierarchy (micro- and nanostructural properties) and phase composition on electric, semiconducting, dielectric and magnetic properties of ceramic materials. Modern characterization methods for ceramic materials. Stereological methods. Fractals and electronic ceramics. Computer technologies in the research, characterization and simulation of novel structures and properties of ceramic materials. Nanostructure and nanotechnology in electronic ceramics. Ceramic materials synthesis technology. Eclectrically conductive ceramics. Ceramic materials for various components, functions and properties: condensers, sensors, ferroelectrics and PTCR and NTCR effects. Optoelectronic ceramics. Optical fibers. Ceramic materials for microwave components of varying frequency ranges. Ferroelectric materials and other ceramic materials in medicine and robotics. Electronic ceramic materials for new energy sources, telecommunications and information technologies. Ceramic materials for space technologies. Ceramic materials and high integration and packaging of electronic components and parameters within microelectronic devices. International trends in manufacturing and recycling of ceramics materials, and global security considerations related to advanced ceramic materials and technologies.□ □		
Practical teaching (exercises, OFE, study and research	Part of the exercises and lectures are performed at institutes, laboratories, companies and the Center for Electronic Microscopy.		
Textbooks/references			
1	M. M. Ristic, Principles of Material Science, SANU Special Edition, DCXVII, (1993). (in Serbian)		
2	D.Raković, Physical basics and characteristics of electrical materials, Belgrade, (1997) (in Serbian)		
3	Vojislav V. Mitić, Structure and electrical properties of BaTiO3 ceramics, Belgrade, Endowment Andrejević, 2001. (in Serbian)		
4	W.D.Callister, “Materials Science And Engineering an introduction, John Wiley&Sons Ltd, 2003		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations, computing and laboratory training			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Software Engineering in Microelectronics		
Lecturer (for lectures)	Pantić S. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The acquisition of advanced knowledge in the field of simulation, design and optimization of technological processes, simulation of electrical characteristics of various microelectronic devices and circuits simulation.		
Course outcomes	Student is able to independently use a number of software tools for the design, optimization and analysis of microelectronic devices, circuits and systems.		
Course outline			
Theoretical teaching	Introduction. Modeling and simulation. The application of computers and software tools in the design of microelectronic components and systems. Design of experiment (DOE). Simulation and modeling of technological processes for the production of microelectronic components. Process modeling of ion implantation, diffusion, oxidation, etching and lithographic processes. Simulation of the electrical characteristics of the components. The system of fundamental semiconductor equations, models of mobility, generation and recombination of carriers. Domain simulation disretizacija and solving systems of partial differential equations. TCAD software tools. Electrical modeling. Models of passive and active components. Parameter extraction. Analytical, physical, numerical modeling and neural networks. Verification and calibration. Structural modeling. 2D and 3D structures. Thermal and mechanical stresses.		
Practical teaching (exercises, OFE, study and research	In the exercises, individual projects, the project (research paper) and exercises that are performed with the help of a computer, the student is trained independently using commercial software tools for design and simulation of technological process and the electrical characteristics of various semiconductor devices.		
Textbooks/references			
1	Драган Пантић, Татјана Пешић, Елва Јовановић, Моделирање и симулација у микроелектроници, Електронски факултет у Нишу, 2005.		
2	J.D. Plummer, M.D. Deal, P.B. Griffin, Silicon VLSI Technology, Prentice Hall, 2000.		
3	Course website		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, active involvement in the implementation of research projects, participate in the educational process at the undergraduate and graduate studies, seminars and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Solar Systems, Technologies and Devices		
Lecturer (for lectures)	Pantić S. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The acquisition of new knowledge in the field of design and practical implementation of solar components, technologies and systems.□		
Course outcomes	Students are able to effectively and efficiently apply accepted knowledge in the field of solar energy technologies.□		
Course outline			
Theoretical teaching	Solar energy. The photovoltaic effect. Generation of charge carriers by the absorption of light. Absorption in direct and indirect semiconductors. Solar cells. The basic mechanisms of energy conversion. Current-voltage characteristics. Photocurrent, saturation currents and ohmic resistance of solar cells. High efficiency solar cells. Structures and processes for high efficiency solar cells. Materials and technologies for the production of Si solar cells. New materials, new concepts and future developments. Types of solar cells. Analysis and characterization of solar cells. Current-voltage characteristics, spectral response. Modeling of solar cells TCAD software tools. Generalized PSpice solar cells. PV systems. Components of PV systems. Types of PV systems. Applications of PV systems and their installation. Small PV systems to power mobile devices. Impact of PV systems. Recycling of PV systems. Price and PV markets. The future of PV systems.□		
Practical teaching (exercises, OFE, study and research	The practical classes are organized by exercises and design of solar systems using different software packages. The practical exercises involving the characterization of the different types of solar modules in existing PV systems, as well as the measurement of basic electrical parameters of solar cells. Visits to the solar power plant, where the students to the practical problems in their constructions.□		
Textbooks/references			
1	Course website		
2	Photovoltaic Devices, Systems and Applications CD-ROM, C. Honsberg and S. Bowden, (free online resource)		
3	Planning and Instaling Photovoltaic Systems, Eartscan UK&USA, 2008.		
4	Photovoltaic Science and Engineering Handbook, Second Edition, Antonio Luque and Steven Hegedus, John Wiley and Sons, 2012.		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Lectures, active involvement in the implementation of research projects, participate in the educational process at the undergraduate and graduate studies, seminars and projects.□

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Technology, Design and Characterization of Microsystems		
Lecturer (for lectures)	Prijić D. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The objectives of the course are such that a PhD student will: - Know the materials used in the production of microsystems; - Know the technological processes used for production; - Understand the process of designing and characterizing microsystems.		
Course outcomes	Learning specific learning outcomes are defined so that a PhD student will: - Distinguish materials used in the production of microsystems; - Distinguish, at the level of detail, technological processes and their order in the production of microsystems; - Explain, at the level of detail, the process of designing and characterizing microsystems; - Design the microsystem, according to the given functional and technical specifications.		
Course outline			
Theoretical teaching	Basic terms. Materials for microsystems - Materials in silicon technologies: monocrystalline silicon, polycrystalline silicon, silicon dioxide, silicon nitride, metal films, polymers. Materials in other technologies: silicon carbide, diamond, gallium arsenide and other III / V semiconductor compounds, piezoelectric ceramics. Material properties and physical effects. Technological processes in the production of microsystems - Standard technological processes: lithographic processes, thin layer deposition processes: CVD processes, PVD processes, Wet and dry etching. Other technological processes: anodic bonding, sol-gel deposition, electrolytic deposition. Technologies of Micro Machines. Surface micromachining, volume micromachining, LIGA, DXRL and EFAB technologies, assembling and integrating microsystems into enclosures. Flow diagram of microsystem design. Characterization of components and subsystems. Integration of analog and digital components of the microsystem. Microsystem power supply. Performance optimization.		
Practical teaching (exercises, OFE, study and research	Study research work in the field of materials, technological processes, design or characterization of microsystems, according to student affinity.		
Textbooks/references			
1	"MEMS: Fundamental Technology and Applications (Devices, Circuits, and Systems)", Ed. by V. Choudharu and K. Iniewski, CRC Press, 2013.		
2	Selected scientific papers (reviews)		
3	N. Maluf and K. Williams, "An Introduction to Microelectromechanical Systems Engineering", 2nd Ed., Artech House, 2004.		
4			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures; Consultations. Active participation in scientific and research projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Reliability Modeling of MOS Devices		
Lecturer (for lectures)	Danković M. Danijel		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Introduction to basic accelerated testing for lifetime estimation in MOS transistors.		
Course outcomes	Theoretical knowledge. The ability to estimate the lifetime of MOS devices under normal operating conditions.		
Course outline			
Theoretical teaching	Accelerated tests for lifetime estimation in MOS transistor. Methods of designing experiments. Bias temperature stressing of MOS transistor. The influence of bias temperature stressing on the electrical characteristics of the transistor. Modeling of electrical parameters of MOS transistors. Voltage (classical model based on linear extrapolation, VG model, 1/VG model, power-law model E-n) and temperature models for lifetime estimation of MOS transistors under normal operating conditions. Determination of the experimental lifetime values. Lifetime estimation - extrapolation to normal operating conditions. Analysis of the influence of the selection of the electrical parameter, the failure criteria, the range of selected voltages and temperatures, and the chosen model for lifetime estimation.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Danijel Danković, „Nestabilnosti p-kanalnog VDMOS tranzistora snage usled naponsko temperaturnih naprezanja sa negativnom polarizacijom gejta“, Elektronski fakultet u Nišu, magistarska teza, 2006.		
2	Danijel Danković, „Nestabilnosti komercijalnih VDMOS tranzistora snage usled naponsko temperaturnih naprezanja oksida gejta“, Elektronski fakultet u Nišu, doktorska disertacija, 2009.		
3	Tibor Grasser, Editor, „Bias Temperature Instability for Devices and Circuits“, Springer, 2014, ISBN 978-1-4614-7909-3.		
4	J.W. McPherson, Editor, „Reliability Physics and Engineering – Time-To-Failure Modeling“, Springer, 2014, ISBN 978-1-4419-6348-2.		
5	M. Tahori, Editor, „Microelectronics Reliability, Special Section: Modelling the Negative Bias Temperature Instability“, Elsevier, 2018, ISSN 0026-2714.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Theoretical teaching, active role in the scientific-research projects, seminars and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Influence of Radiation on Microelectronic Devices		
Lecturer (for lectures)	Golubović M. Snežana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Gaining knowledge about the types of radiation and their effects on microelectronic components.		
Course outcomes	Knowing the effects of radiation, with special emphasis on the effects of gamma radiation in microelectronic devices and their annealing.		
Course outline			
Theoretical teaching	Properties of gamma and neutron radiation. Defects caused by radiation in microelectronic devices. The impact of radiation on the electrical characteristics of microelectronic devices. Mechanisms of instability characteristics in microelectronic devices. Annealing of defects.□		
Practical teaching (exercises, OFE, study and research	Seminar work		
Textbooks/references			
1	S. Golubovic, S. Djoric Veljkovic, I. Manic, V. Davidovic, Stress effects in gate oxide of power VDMOS transistors (monography), Faculty of electronics, University of Nis, 2006. (in Serbian)		
2	R.D. Scrimpf, D.M. Fleetwood (editors), Radiation effects and soft errors in integrated circuits and electronic devices, Vanderbilt University, USA, 2004.		
3	S. Golubovic, Analysis of creation and annealing of radiation effects in MOS transistors, Doctoral thesis, Faculty of electronics, University of Nis, 1995. (in Serbian).		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentation on a given topic.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electrical Machines and Energy Efficiency		
Lecturer (for lectures)	Stajić P. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Main topic of this course is to introduce students with the role that electrical machines have in the process of increasing energy efficiency of different industry systems, with strategy of developed countries for energy efficiency increasing, with measurement of electrical machines characteristics, with electrical machines energy efficiency assessment techniques, and methods for increasing energy efficiency with best practice examples.		
Course outcomes	Students capable to perform measurements of electrical machine characteristics and to analyze and determine electrical machines energy efficiency. Also, students will be familiar with new solutions applied in developed countries for increasing energy efficiency and will be able to select and implement energy efficiency optimization in practice.		
Course outline			
Theoretical teaching	Operating characteristics of electrical machines. Application of electrical machines (pump station, compressor station, fans, heating and cooling systems, transport and logistics systems, renewable energy sources and other). Electrical machines energy efficiency throughout the life cycle. Energy efficient electrical machines. European Union strategy for increasing energy efficiency of electrical machines and drives. Interdisciplinary approach to energy efficiency solutions in industry. Measurement of energy efficiency of electrical machines. Barriers for energy efficiency increasing. Theoretical and methodological approach for energy efficiency increasing. Energy efficiency management: theory and best practice examples.		
Practical teaching (exercises, OFE, study and research	Part of the course is conducted through mentoring and part through individual research and study work in the field of electrical machines and transformer. Through mentoring, students are introduced with the subject content. The study and research work is based on active study of primary scientific sources, analysis of electrical machine systems energy efficiency with the aim to increase efficiency, performing of experiments in systems with electrical machines and proposing and implementing measures for energy efficiency increasing.		
Textbooks/references			
1	P. Tolander, J. Palm ”Improving Energy Efficiency in Industrial Energy Systems”, Springer-Verlag, London, 2013.		
2	A. Emadi, J.C. Andreas ”Energy-Efficient Electric Motors”, Marcel-Dekker, New York, 2005.		
3	F. Parasiliti, P. Bertoldi ”Energy efficiency in motor driven systems”, Springer-Verlag, Berlin, 2003.		
4	D. R. Wulfinghoff ”Energy Efficiency Manual”, Energy Institute Press, Marylend, U.S.A. 1999.		
5	A. de Almeida,P. Bertoldi, W. Leonhard ”Energy Efficiency Improvements in Electric Motors and Drives”, Springer-Verlag, Berlin Heidelberg, 1997.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures via the presentation, discussions and consultations. Assistance in performing experiments and prepare students for independent research and scientific papers publishing.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electrical Drives - Selected Chapters		
Lecturer (for lectures)	Mitrović N. Nebojša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Students are introduced to characteristic industrial applications of drives, methods of analysis, integration of necessary equipment, parameterization, commissioning and supervision.		
Course outcomes	Students are capable for independent analysis of operation in stationary and transient regimes, modelling of mechanical couplings, design of control algorithms and application of multi-motor drives.		
Course outline			
Theoretical teaching	Introduction. Electrical drive as a prime mover of an industrial process. Interfacing with a higher level control. Modelling of electrical drives. Control of electric drives. Power converter-motor-load systems. Multiquadrant operation. Parameter identification and estimation. Measurement of drive and process variables. AC motor drives. Coordinate transformation. Parameter estimation. Voltage and current fed converters. Induction motor drives. Scalar and vector control methods. Realization of modern control technique. Influence of parameters detuning. Sensorless operation. Synchronous motor drives. Control of synchronous machines. Scalar control. Vector control. Large power drives. Sensorless operation. AC machine of special construction and its applications in drives.		
Practical teaching (exercises, OFE, study and research	Part of the course is conducted through individual research and study work in the field of electric motor drives. The study and research work are based on an active study of primary scientific sources, numerical simulations and organization and performance of experiments.		
Textbooks/references			
1	S .N. Vukosavic, "Digital Control of Electric Drives", Springer, 2007		
2	Piotr Wach, "Dynamics and Control of Electrical Drives", Springer, 2011		
3	B. Jeftenic, M. Bebić, S. Štatkić, "Multimotor electrical drives", Akademska misao, Belgrade 2011		
4	R. Krishnan, "Electric Motor Drives", Virginia Tech, Prantice Hall 2001		
5	P. C. Krause, O. Wasynczuk, ..."Analysis of Electric Machinery and Drive Systems", Willey 2013		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures via the presentation of the necessary literature, tutorials and help in laboratory work. Study, research and independent work in the laboratory.□			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	40
Colloquia			
Projects	60		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Diagnosis and Condition Monitoring of Electrical Machines		
Lecturer (for lectures)	Petronijević P. Milutin, Mitrović N. Nebojša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	None		
Course objectives	The study of modern methods of diagnosis and monitoring of electrical machines in electric drives with and without power electronics converters. Study of conventional and advanced techniques of parameter estimation and states of electrical machines. Application and development of advanced methods for the analysis of electrical and non-electrical quantities.		
Course outcomes	Students will be able to independently analyze the operating conditions of electrical machines and evaluate reliability of the electrical drives. The students will be capable to develop new methods for the analysis and estimation of electric machines states.		
Course outline			
Theoretical teaching	Electric machine equations in the stationary and general reference frames: voltages, currents, torque and power. Real time signal processing. Motor current signature analysis. Monitoring the stator, rotor, and magnetizing flux linkage space phasor, practical implementation. Monitoring of the rotor speed and angle. The application of conventional techniques: tachometers, encoders, resolvers. Rotor slip and speed estimation. Torque and flux estimation. Stator frequency and rotor speed estimation utilizing the leakage flux. Estimation in inverter-fed electric drives. Estimation of the inertia. Standstill response test. Condition Monitoring. Non-invasive condition monitoring. Application of thermal vision. Eccentricity and broken cage diagnostic methods. Vibration monitoring. Application of machine learning.		
Practical teaching (exercises, OFE, study and research	The part of teaching includes study and research work in the course area. It involves active studying of the basic scientific sources, computer simulations, performing of experiment in laboratory, solving research tasks and evaluation new scientific methods in the field.		
Textbooks/references			
1	P. Vas, “Parameter Estimation, Condition Monitoring and Diagnosis of Electrical Machines”, Clarendon Press Oxford, 1993		
2	P. C., Krause, .., ”Analysis of Electric Machinery and Drive Systems”, IEEE Press 2002		
3	H. A. Toliyat, S. Choi, H. Meshgin-Kelk, S. Nand, "Electric Machines: Modeling, Condition Monitoring, and Fault Diagnosis", CRC Press, 2012		
4	Peter Tavner, Li Ran, Jim Penman and Howard Sedding, "Condition Monitoring of Rotating Electrical Machines", 2nd Edition, IET, 2008		
5	Faiz, J.; Ghorbanian, V.; Joksimovic, G. (ed.): "Fault Diagnosis of Induction Motors" , IET Digital Library. 2017		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching includes lectures and consultations, as well as individual work with the students during study and students research work presentation at conferences.			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Distribution Systems		
Lecturer (for lectures)	Korunović M. Lidija		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Studying of up to date distribution systems, balanced and unbalanced distribution networks, load flow calculation, calculation of faulty conditions, voltage regulation, the ways of power flow control and load management, and calculation of networks with distributed generation.		
Course outcomes	Knowledge of up to date distribution system operation. Knowledge of mathematical methods for the analysis of distribution network operating regimes.		
Course outline			
Theoretical teaching	Concepts of European and American distribution networks, as representatives of all types of distribution networks. Unbalanced distribution networks and unbalanced operating conditions. Load flow calculation and calculation of faulty conditions of balanced and unbalanced distribution networks. Voltage regulation in distribution networks. The ways of power flow control and load control in distribution networks. Load flow calculation in steady state condition and short-circuit analysis in the networks with small generations.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	T.Gonen, Electric Power Distribution System Enginering, CRC Press, Taylor & Francis Group, Boca Raton, 2008.		
2	L. M. Korunović, Load Model Parameters of Distribution Network (in Serbian), Library dissertatio, Foundation Andrejević, Belgrade, 2010.		
3	V. Strezoski, D. Janjić, System for Voltage Regulation in Distribution Networks (in Serbian), Institute for Power Engineering and Electronics, FTN Novi Sad, 2008.		
4	J. Nahman, V. Mijailović, Reliability of Electric Power Distribution Systems (in Serbian), Academic mind, Belgrade, 2009.		
5	A. Keyhani, M. N. Marwali, M. Dai, Integration of Green and Renewable Energy in Electric Power Systems, John Wiley & Sons, Hoboken, New Jersey, 2010.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teching includes the classic lectures and consultations. It comprehends the interactive work with students in different areas of modern distribution systems, related to the study of scientific literature, computer simulations and the work on seminar paper.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Planning and Operation of Power Networks		
Lecturer (for lectures)	Janjić D. Aleksandar		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the planning and operation of power networks principles in deregulated environment. The emphasis is on the usage of moder optimization techniques for the maintenance planning and unit comitment for the participation in the spot market.		
Course outcomes	Students will be capable for the application of appropriate optimization technique for the short term and long term planning of operation in power networks. Furthermore, they will be capable to performe the risk analysis of assets evaluation and investment planning.		
Course outline			
Theoretical teaching	Planning and the operation in the deregulated market. Decision making techniques in restructured power sector using fuzzy logic. Short term and long term maintenance planning of generation units.Short term and long term maintenance planning of networks. Coordination between short term and long term planning. Short term pricing and unit commitment on the market. Risk analysis.		
Practical teaching (exercises, OFE, study and research	Part of this course is effectuated through the independent work regarding the application of modern optimization techniques. Active litterature review, numerical simulations.		
Textbooks/references			
1	M. Shahidehpour, M. Marwali :"Maintenance scheduling in restructured power systems",□ Kluwer academic publishers, USA, 2000..		
2	Y-H. Song: "Modern optimization techniques in power systems", Kluwer academic publishers, USA, 1999.		
3	M. Shahidehpour, H. Yamin, Zuyi Li:" Market Operations in Electric Power Systems: Forecasting, Scheduling, and Risk Management",IEEE 2002		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Litterature review. Consultations. Assistance with the simulations. Independent work at optimization problem solving.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Grounding and Grounding Systems		
Lecturer (for lectures)	Cvetković N. Nenad, Tasić S. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The aim of the course is to familiarize students with the characteristics and types of grounding and grounding systems, as well as with the methods for the calculation and analysis of the grounding systems' characteristics.		
Course outcomes	Students will be trained to perform the calculation and analysis of the characteristics of complex grounding systems using different numerical methods in the frame of personally realiyzed or commercial program packages which provide possibility for simulation of grounding systems.		
Course outline			
Theoretical teaching	Stationary and quasi-stationary characteristics of grounding systems. Structure of the electromagnetic field and potential in the vicinity of the grounding in linear, isotropic, homogeneous and non-homogeneous soil structure. Calculation of unknown current distribution, leakage currents and integral characteristics of different grounding systems: grounding impedance, touch and step voltages. Derivation of the system of integral equations for the analysis of EM characteristics of grounding systems. Approximate methods for solving systems of integral equations: method of moments, point-matching method, average potential method, equivalent electrodes' method, the finite element method, the estimation method. Frequency characteristics of grounding systems. Overhead and cable lines as elements of grounding systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	E. B. Joffe, K-S. Lock, Grounds for Grounding: A Circuit to System Handbook, Wiley-IEEE Press, 2010		
2	E. D. Sunde, Earth Conduction Effects in Transmission Systems, Dover Publications, New York, 1968.		
3	В. В. Бургсдорф, А. И. Якобс, Electrical grounding devices, Энергоатомиздат, Moscow, 1987. [in Russian]		
4	J. Nahman, Neutral Grounding of Distribution Networks, Naučna knjiga, Belgrade, 1980. [in Serbian]		
5	A. P. Sakis Meliopoulis, Power System Grounding and Transients: An Introduction. Series: Electrical and Computer Engineering, CRC Press1988		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching, consultations, research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Optimisation Methods in Power Engineering		
Lecturer (for lectures)		Tasić S. Dragan, Marinković D. Slađana		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	The objective of the course is to prepare students to be independent in application of modern optimization methods and solving complex power system optimisation problems.			
Course outcomes	After finishing this course, students will be able to apply the modern optimization methods and to solve complex power system optimisation problems.			
Course outline				
Theoretical teaching	Significance of the power system optimization methods. Definition of the optimization problem. Linear programming. Simplex and dual simplex. Transport problem. Network Flow programming. Illustrations on power system problems. Nonlinear programming. Gradient methods. Newton's and Quasi-Newton's methods. Quadratic programming. Illustrations on power system problems. Complex optimisation problems. Illustrations on power system problems. Dynamic, Geometric and Multi-objective programming and their application for solving power system problems. Metaheuristic methods and their application on power system optimization. Typical static and dynamic optimization problems: optimal power flow, optimal planning problems, unit commitment problems, voltage-reactive power static and dynamic optimization problems.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	J. A. Momoh, Electric Power System Application of Optimization, Marcel Dekker, New York, 2009.			
2	J. Radosavljević, Metaheuristic Optimization in Power Engineering, IET The Institution of Engineering and Technology, 2018.			
3	A. Savić, D. Šošić, G. Dobrić, M. Žarković, Methods of optimization - Applications in electric power, Akademska misao, Belgrade, 2018. (in Serbian)			
4	Y.H. Song (Editor), Modern Optimization Techniques in Power Systems, Kluwer Academic Publishers, 1990.			
5	Д. А. Арзамасцев, А. В. Липес, Оптимизационные модели развития электрических сетей энергосистем, Уральский политехнический институт, Свердловск, 1987.			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, Discusions, Research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Electromagnetic Compatibility		
Lecturer (for lectures)	Javor L. Vesna		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	Knowledge of basic principles and techniques of electromagnetic compatibility		
Course objectives	Study of advanced topics in the field of electromagnetic compatibility: design of devices and systems, electrostatic discharges, atmospheric discharges, intentional electromagnetic interference and data protection of electromagnetic signals from the detection.		
Course outcomes	Ability to design devices and systems in accordance with electromagnetic compatibility requirements. Contribution to the study of electrostatic discharges, principles and techniques of intentional electromagnetic interference and detection of electromagnetic signals.		
Course outline			
Theoretical teaching	Practical problems in electromagnetic compatibility (EMC) testing. Modeling the occurrence of electrostatic discharge, compliance with the standards in this field and EMC techniques. Testing the EMC with the power supply network and measures for improving power quality. Electromagnetic interference due to lightning discharges (LEMP) and nuclear explosions (NEMP). Detection of unintentional electromagnetic signals (TEMPEST) and causing intentional disturbances. Application of EMC techniques in the design of devices and systems. Modern equipment of laboratories for testing EMC.		
Practical teaching (exercises, OFE, study and research	Practical lectures are realized through exercises on the computer and participation in testing of devices in the laboratory for testing electromagnetic compatibility.		
Textbooks/references			
1	Ott H. W., "Electromagnetic compatibility engineering," John Wiley & Sons, 2009.		
2	Williams T., "Electromagnetic compatibility for product designers," Newnes, 2016.		
3	Đorđević A., Olćan D., "Electromagnetic compatibility testing," (in Serbian), Academic Mind, Belgrade, 2012.		
4	Keiser K., "Electromagnetic compatibility handbook," CRC Press, 2004.		
5	Rachidi F., Tkachenko S., "Electromagnetic field interaction with transmission lines", WIT Press, 2008.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures and consultations. Testing device compliance with EMC standards and EMC testing laboratory activities.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Electrical Machines and Transformes - Selected Chapters		
Lecturer (for lectures)		Stajić P. Zoran		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Main topic of this course is to introduce students with specific working modes of electrical machines and transformers but also with potential applications of the theory in solving various practical problems that arise during the exploitation.			
Course outcomes	Students capable to apply the theory of electrical machines and transformers to solve various practical problems that arise during the exploitation. Depending on the types of problems, students will be able to make the optimal choice of measuring equipment needed to determine the model parameters. Also, students will be introduced with the techniques with which it is possible to see electric machines and transformers as “measuring device” with which different system parameters can be obtained.			
Course outline				
Theoretical teaching	Description of a number of specific problems arising during the exploitation of electrical machines and transformers in various industries. Analyses and choice of approach for problem solving. Optimal selection of measuring and test equipment for testing in service conditions. Analysis and choice of optimal mathematical model for a given service conditions. Useful softwares for conducting different analysis. The link between theory and practice. Examples of best practice in the implementation of simple and complex models, depending on the available data and the results of the experiments. Analysis of the obtained results. Observation of electric machines and transformers as a "measuring device" based on its behavior to obtain detailed information of the systems in which these devices operate.			
Practical teaching (exercises, OFE, study and research	Part of the course is conducted through mentoring and part through individual research and study work in the field of electrical machines and transformers. Through mentoring, students are introduced with the course content. The study and research work is based on active study of primary scientific sources, on numerical simulations and organizing and carrying out experiments in service conditions of electrical machines and transformers.			
Textbooks/references				
1	P. C. Krause, O. Wasynczuk, S. Sudhoff, ”Analysis of Electric Machinery and Drive Systems”, IEEE Press 2002			
2	M. J. Heathcote, ”J&P Transformer Book”, Elsevier, Book Aid International, England, 2007.			
3	S. Vukosavic, Electrical Machines”, Academic mind, Belgrade, 2010. (in Serbian)			
4	J. Hindmarsh, ”Electrical Machines and their Applications”, Faculty of U.M.I.S.T. England, 1984.			
5				
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures via the presentation, discussions and consultations. Assistance in performing experiments and prepare students for independent research and writing scientific papers.			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**	**Points**	
Activity during lectures		**Written exam**		
Exercises		**Oral exam**	50	
Colloquia				
Projects	50			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electrical Machines and Power Converters for Renewable Energy Sources		
Lecturer (for lectures)	Petronijević P. Milutin, Mitrović N. Nebojša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	None		
Course objectives	The study of machines and converters specificities for application in the field of renewable energy. The study of advanced control techniques and analysis of the power quality effects on the operation of the power converter. Analysis of the distribution network effects on the power electronic converter operation. Micro-grid architecture, operation and control.		
Course outcomes	At the end of the course, students will be qualified for independent analysis of machines and converters for applications in distributed power sources. Competence to solve the actual problems in selection of machine types and power converters topologies and control methods.		
Course outline			
Theoretical teaching	Topologies of grid-side converters. Wind turbines with fixed and variable speed operation - DFIG, back-to-back power converters. Photovoltaic sources. DC/DC voltage converters. Energy storages. Optimization of power flow. Stationary and dynamic modes of operation. Grid synchronization and power flow control. Standalone operation. Coordinated control of converters in micro-grid. Power quality effects on the grid converters operation: voltage dips, surges, short circuits. Micro-grid networks integration.		
Practical teaching (exercises, OFE, study and research	The part of teaching includes individual study and research work in the course area. It involves active studying of the basic scientific sources, computer simulations, and performing of experiment in laboratory.		
Textbooks/references			
1	Fuch, E.F.; Masoum, M.A.S."Power Conversion of Renewable Energy Systems," Springer, 2011		
2	Remus Teodorescu, Marco Liserre, Pedro Rodríguez, "Grid Converters for Photovoltaic and Wind Power Systems," Wiley, 2011.		
3	Gonzalo Abad, Jesus Lopez, Miguel Rodriguez, Luis Marroyo, Grzegorz Iwanski, "Doubly Fed Induction Machine: Modeling and Control for Wind Energy Generation (IEEE Press Series on Power Engineering)", IEEE, 2011.		
4	Ruan, X., Wang, X., Pan, D., Yang, D., Li, W., Bao, C, "Control Techniques for LCL-Type Grid-Connected Inverters", Springer, 2017.		
5	Qing Chang Zhong T. Hornik, "Control of power inverters in renewable energy and smart grid integration", Wiley, 2013.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching includes lectures and consultations, as well as individual work with the students during study and students research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Control of Electrical Drives and Power Converters		
Lecturer (for lectures)	Petronijević P. Milutin		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	None		
Course objectives	The study of modern control methods for electric drives and converters based on digital signal processors. Study of conventional and advanced control techniques and analysis on the power quality effects on converter and motor operation.		
Course outcomes	Students will be able to independently analyze and design converters control method for applications in drives with DC and AC motors. Competence to solve the actual problems in the field of digital control of power converters and drives.		
Course outline			
Theoretical teaching	Digital signal processors in motor drives. Control circuits for AC and DC drives. Principles, types and classification of pulse width modulation (PWM) techniques. Space vector modulation. Matlab DSP and FPGA Toolbox. Optimization of control methods. Over-voltages and leakage currents. The influence of power disturbances on the power converter and motor operation. Active front-end rectifier and grid converter. Nonsymmetrical supply of power converters. Vector control of drives with induction motors. Digital control of current and speed. Control of permanent magnet motor drives. Estimation of electrical and non-electrical quantities.		
Practical teaching (exercises, OFE, study and research	The part of teaching includes study and research work in the course area. It involves active studying of the basic scientific sources, computer simulations, and performing of experiment in laboratory with different types of converters and motors.		
Textbooks/references			
1	S. N. Vukosavic, "Digital Control of Electrical Drives", Springer, 2007.		
2	Vladan Vucković, Electric drives, University of Belgrade, 1997 (in Serbian)		
3	M. P. Kazmierkowski, R. Krishnan, F. Blaabjerg, Control in Power Electronics – Selected Problems, Academic Press, 2003		
4	D. Grahame Holmes, Thomas A. Lipo, "Pulse Width Modulation for Power Converters: Principles and Practice (IEEE Press Series on Power Engineering," IEEE, 2003.		
5	N. Mitrović, V. Kostić, M. Petronijević, B. Jeftenić: “Implementation of torque and flux control algorithms for induction motor drives”, Faculty of electronic Engineering, Niš, Serbia, 2009 (in Serbian).		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching includes lectures and consultations, as well as individual work with the students during study and research work. Student seminar work and/or scientific papers preparation and presentation.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Computation of Lightning Overvoltages		
Lecturer (for lectures)	Javor L. Vesna		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites	Knowledge of transmission line theory and electromagnetic fields theory		
Course objectives	Study of different models of lightning electromagnetic fields and the impact of the finite conductivity of the ground. Determination of lightning overvoltages on lines using modified telegrapher equations.		
Course outcomes	Contributions to the improvement of modeling of lightning overvoltages on lines. Realization of subroutines for implementation in computer programs for simulation of lightning overvoltages.		
Course outline			
Theoretical teaching	Modeling of lightning electromagnetic fields. Modified telegraphers' equations that include the influence of the external electromagnetic field. Taylor-Satterwhite-Harrison model. Agrawal-Price-Gurbaxani model. Rachidi model. Modeling losses and impacts of the finite conductivity of the ground. Baum-Liu-Tesche equations. Overvoltages propagation on overhead lines. Overvoltages propagation on underground lines. Electrodynamic correction of the equations of classical transmission line theory. Solving equations in the time domain by the Finite Difference Method. Solving the equations for the propagation of electromagnetic waves on lines in the frequency domain. Computer programs for simulation of lightning overvoltages in power systems.		
Practical teaching (exercises, OFE, study and research	Practical lectures are realized using computer programs for the computation of lightning electromagnetic fields and overvoltages in electric power systems.		
Textbooks/references			
1	Rakov V. A., Uman M. A. "Lightning physics and effects“, Cambridge Univ. Press, UK, University Press, 2005.		
2	Rachidi F., Tkachenko S., "Electromagnetic Field Interaction with Transmission Lines", WIT Press, 2008.		
3	Javor V., "Lightning electromagnetic field," (in both Serbian and English), Andrejević Endowment, Belgrade, 2011.		
4	Stojković Z., "Computer aided design in power engineering," (in Serbian), Academic Mind, Belgrade, 2002.		
5	Betz H.-D., Schmidt K., Oetttinger W.P, Wirz M. "Lightning: principles, instruments and application“, Springer, Dordrecht, NL, 2008.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations and exercises on the computer.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Power Cable Engineering		
Lecturer (for lectures)	Tasić S. Dragan, Raičević B. Nebojša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The aim of the course is that students learn modern methods for the calculation of electrical and thermal fields in the cables, joints and cable terminations, cable ampacity in various service conditions and estimation of the lifetime of cables.		
Course outcomes	Upon completion of this course, students will be trained in understanding phizics of the problem and solving the complex problems of construction and operation of electric power cables and cable accessories.		
Course outline			
Theoretical teaching	Finite element method. Equivalent electrode method. Boundary conditions for the electrical field calculation. Calculation of the electrical field in single and three-wire cables, joints and terminations. Boundary conditions for the calculation of thermal field. Calculation of thermal fields in single and three-wire cables, joints and terminations. Calculation of cable ampacity in working conditions. Aging of cables. Cable lifetime estimation. Calculation of ampacity with respect to cable aging.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. Tasić, Basics of Power Cable Engineering, Press Series: Textbooks, Faculty of Electronic Engineering, Niš, 2001. (in Serbian)		
2	G. J. Anders, Rating of Electric Power Cables in Unfavorable Thermal Environment, IEEE Pres, 2005		
3	A. B. J. Reece, T. W. Preston, Finite Element Methods in Electrical Power Engineering, Oxford University Press, 2000.		
4	IEC 60287, IEC 60853, . IEC 62095		
5	Cigre Report JWG 21/33		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, discussions and research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Power Quality in Distribution Networks		
Lecturer (for lectures)	Korunović M. Lidija		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The objective of the course is to introduce up to date problems of power quality in distribution networks to the students, and to habilitate them to apply contemporary scientific literature, valid standards, recommendations and other technical literature. Students should be habilitated to perform complex measurements of power quality indices in the laboratory and in the field.		
Course outcomes	Students will be habilitated to analyse and research wide range of power quality issues in up to date distribution networks, to apply and create standards, recommendations and other technical instructions, as well as to plan and to perform measurements of power quality indices in laboratory and in high voltage substations.		
Course outline			
Theoretical teaching	Importance of power quality for operation of distribution networks. Basic terms and definitions, importance and relevancy, tolerance limits. Methods of measurement and monitoring of power quality indices - advanced measuring systems. Voltage variations in steady state operating conditions and flicker - definitions, sources and effects. Voltage dips - definitions, characteristics, causes, propagation and effects. Sensitivity of the equipment on voltage dips and estimation of financial losses. Harmonics - definitions, sources and effects. Methods of the analysis of higher harmonics. Propagation of harmonics - calculation of the flows of higher harmonic currents. Methods of the elimination of higher harmonics. Design and calculation of filters. Overview of the international regulation and standards.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	R. Dugan, M. McGranaghan, S. Santoso, H. W. Beaty, Electrical Power System Quality, Second Edition, McGraw-Hill Companies, 2002.		
2	V. Katić, Power Quality - Higher Harmonics (in Serbian), memoir, Faculty of Technical Sciences, Novi Sad, 2002.		
3	M. H. J. Bollen, Unerstanding Power Quality Problems, IEEE, Wiley, 2000.		
4	596 CIGRE/CIRED JWG C4.112, Guidelines for Power Quality Monitoring - Measurement Locations, Processing and Presentation of Data, Final Report, CIGRE, 2014.		
5	M. M. Kostić, Reactive Energy Compensation and Higher Harmonics in Electric Networks (in Serbian), memoir, Electrical Engineering Institute Nikola Tesla, Belgrade, 2014.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching includes the classic lectures and consultations regarding different issues of power quality in distribution networks. The individual work with students includes the study of different scientific sources, laboratory and field measurements, and the work on seminar paper.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Active Distribution Networks and Microgrids		
Lecturer (for lectures)	Janjić D. Aleksandar		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the basic characteristics of distribution network with distributed generation, designed to the supply of microgrids, that can work independently of power distribution network.		
Course outcomes	Students will be qualified for the design of microgrid for the supply of particular area, including: the choice of distributed generation resource, control mechanism, energy storage system, and system for the synchronisation with the public network.		
Course outline			
Theoretical teaching	Active networks and microgrids concepts. Typical configuration of microgrids. Interconnection and dynamic connection with the public network. Technical and economic advanteges. SCADA and active distribution networks. Control of microgrid in the island operation mode. Protection of microgrids in the island operation mode. Impact of microgrids to other generation resources. Microgrids economy and the participation to the market.		
Practical teaching (exercises, OFE, study and research	Part of this course is effectuated through the independent work regarding the application of modern optimization techniques. Active litterature review, numerical simulations regarding microgrids economy and the participation to the market.		
Textbooks/references			
1	S.P.Chowdhury, P.Crossley, S.Chowdhury:" Microgrids and active distribution networks", IET, London, 2009.		
2	R. Majumder: "Microgrid : Stability Analysis and Control: Modeling, Stability Analysis and Control of Microgrid for Improved Power Sharing and Power Flow Management" VDM Publishing, 2010		
3	M. Shahidehpour, H. Yamin, Zuyi Li:" Market Operations in Electric Power Systems: Forecasting, Scheduling, and Risk Management",IEEE 2002.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Litterature review. Consultations. Assistance with the simulations. Independent work at optimization problem solving.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Methodologies for Representation and Implementation of Future Computer		
Lecturer (for lectures)	Milentijević Z. Ivan, Ćirić M. Vladimir		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Familiarize students with the features and current limitations that exist in computer technology, as well as new techniques for improving performances of hardware and software systems.		
Course outcomes	Students should know how to present advanced architecture (hardware and software), as well as to make tradeoffs in design.		
Course outline			
Theoretical teaching	Trends in computing. Overcoming the limits of existing technologies. Design requirements and basic characteristics of modern and next generation computing technologies. Advanced computer architectures. Potentials of new technologies. Methods of formal representations in modern computer technologies (IOT, dew, fog, cloud). Design methods. New approaches to optimization problems. DNA computing. Quantum computing.		
Practical teaching (exercises, OFE, study and research	Individual research		
Textbooks/references			
1	William Stallings, Computer Organization and Architecture: Designing for Performance, 10th edition, Pearson Prentice Hall, 2016.		
2	Hennessy J., Patterson D., Computer Architecture A Quantitative Approach, Morgan Kaufmann, 2017.		
3	Internet of Things, Buyya R., Dastjerdi A.V (Eds.), Morgan Kaufman, 2016.		
4	Internet of Things - From Research and Innovation to Market Deployment, Vermesan O., Friess P. (Eds.), River Publishers, 2014.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, guided discussions, projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Signals and Systems		
Lecturer (for lectures)	Janković S. Dragan, Stojković R. Suzana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Signals, systems and transformation, from theoretical mathematical foundations to practical implementation with circuit and program implemented algorithms. Methods of analysis signals and systems with applications in filtering, signal processing, communications, and process control. Convolution, spectral transformation algorithms for the calculation of the spectral transform, sampling methods, and discrete signal processing.		
Course outcomes	Students should gain sufficient knowledge of the practical application of the theory of signals and systems in the analysis, design and practical implementation of relatively simple systems.		
Course outline			
Theoretical teaching	Signals, systems and transformation, from theoretical mathematical foundations to practical implementation with circuit and program implemented algorithms. Methods of analysis signals and systems with applications in filtering, signal processing, communications, and process control. Convolution, spectral transformation algorithms for the calculation of the spectral transform, sampling methods, and discrete signal processing.		
Practical teaching (exercises, OFE, study and research	Independent research		
Textbooks/references			
1	Popovic, M., Signals and systems, Nauka, 2007.		
2	Stankovic, R. S., Moraga, C., Astola, J. Fourier Analysis on Finite Groups With Applications In Signal Processing And System Design, John Wiley And Sons Ltd (United States), 2005.		
3	Stankovic R. S., Astola J. T.,: Spectral Interpretation of Decision Diagrams , Springer, 2003.		
4	Oppenheim, A.V., Willsky, A.S., Signals & Systems, Prentice Hall, 1996.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, students work independently on projects, consultations			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Computer Hardware Design		
Lecturer (for lectures)	Milentijević Z. Ivan, Milovanović I. Emina, Ćirić M. Vladimir		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Familiarize students with advanced topics in computer hardware design.		
Course outcomes	Students should know hardware design flow, as well as advanced hardvare description and streaming processor description languages.		
Course outline			
Theoretical teaching	Design flow. Simulation and synthesis environments. Arithmetic circuits. Arithmetic circuits design. Arithmetic circuits HDL models. Tradeoffs in design. Advanced hardware description languages. Synthesis. Advanced computer components. Data stream computing model. Big-data problem. Dataflow supercomputers design techniques. Kernel and manager design. Simulation. The implementation of streaming processors. Compunication between streaming procesors and CPU. Integrated approach. Design of microprogramming controllers, arithmetic and graphics accelerators, and additional memory systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	High-Performance Computing Using FPGAs, Vanderbauwhede W., Benkrid K. (Eds.), Springer, 2013.		
2	FPGAs for Software Programmers, Koch D., Hanning F., Ziener D. (Eds.), Springer, 2016.		
3	Dataflow Programming with MaxCompiler, Maxeler Texnologies Inc, 2012.		
4	Guide to FPGA Implementation of Arithmetic Functions, Deschamps J.P., Sutter G.D., Canto E., Springer, 2012.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, individual student projects, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Software Engineering		
Lecturer (for lectures)	Rančić D. Dejan, Milosavljević Lj. Aleksandar		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to current research topics in the field that cover methods, tools, and techniques for the development and evolution of software systems.		
Course outcomes	Students need to get acquainted with the modern technology of software processes and to gain a critical approach to their evaluation. Students should be able to research in software engineering of advanced software systems, such as multimedia systems, geographic information systems, command information systems, mobile and distributed systems, knowledge-based systems, e-systems.		
Course outline			
Theoretical teaching	Advanced concepts in software modeling and analysis. Advanced concepts of software engineering (service-oriented architecture, model-driven architecture, agile software development). Software development based on components. Web services. Design and development of open source software. Engineering of multimedia information. Engineering GIS applications. Engineering C4I applications. Web and distributed application engineering. Engineering of mobile services and systems. Human-computer interaction from the perspective of software engineering. Software maintenance and evolution.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	I. Sommerville, Software Engineering, 9th ed., Addison-Wesley, 2011.		
2	R. Pressman, Software Enginnering A Practitioner's Approach, 7th ed., McGraw-Hill, 2010.		
3	B. Bruegge, A. Dutoit, Object-Oriented Software Engineering using UML, Patterns, and Java, 3rd ed., Prentice Hall, 2010.		
4	S. Schach, Object-Oriented and Classical Software Engineering, 8th ed., McGraw-Hill, 2011.		
5	C. Jones, Software Engineering Best Practices, McGraw-Hill, 2010.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations, independent study research.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Data and Knowledge Engineering		
Lecturer (for lectures)	Stoimenov V. Leonid, Stojković R. Suzana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to current research topics in the field of data and knowledge engineering, advanced concepts and database models, modern database applications, information retreival, information integration, e-systems, data and knowledge engineering and mining. □		
Course outcomes	Students will learn about actual problemes and solutions for data and knowledge engineering process. Students will be able to do research in the field of data and knowledge engineering, and will be able to apply modern and actual technologies in this research area.		
Course outline			
Theoretical teaching	Advanced concepts and models, including active, deductivem spatial, temporal, multimedia, distributed and mobile databases. NoSQL databases and new concepts in data storage and organization. Big data concepts, aquisition, storage and manipulation of big data. Systems for big data management. Social networks as data sources. Information retreival. Intelligent search agents on teh Web. Knowledge and knowledge representation, semantics and ontologies. Big knowledge bases. Data mining in spatial databases, in multimedia databases, Web mining, text mining. Modern applications for databases and knowledge bases: document databases, Web and databases, e-bussiness, e-Government, e-Learning, data warehouse, data mining.		
Practical teaching (exercises, OFE, study and research	Design, development and implementation of data processing and data analysis systems. Design, development and implementation of a knowledge-based system. Using an open source code for the implementation of the data processing and knowledge processing system.		
Textbooks/references			
1	R. Emasri, S. Navathe, Fundamentals of Database Systems, Pearson; 7 edition (2016), ISBN 10: 1292097612 ISBN 13: 9781292097619		
2	S. Russel, P. Norvig, Artificial intelligence - A Modern Approach, Pearson, 3rd edition, (2016), ISBN-10: 1292153962, ISBN-13: 978-1292153964		
3	J.Han, M. Kamber, J. Pei, Data Mining: Concepts and Techniques, The Morgan Kaufmann Series in Data Management Systems, 3rd Edition, (2011), ISBN-10: 9780123814791, ISBN-13: 978-9380931913		
4	Erl, Khattak & Buhler, Big Data Fundamentals: Concepts, Drivers & Techniques (2016), Prentice Hall, ISBN-13: 9780134291079		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	The course consists of lectures, student presentations, homework and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Distributed Systems		
Lecturer (for lectures)	Stojanović H. Dragan, Stojanović M. Natalija, Janković S. Dragan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring scientific, theoretical and practical knowledge, as well as hardware and software concepts of advanced distributed systems.		
Course outcomes	Students should be qualified for application of scientific and professional knowledge on distributed systems and further independent scientific and research work.		
Course outline			
Theoretical teaching	Distributed computing systems. Cluster and grid systems. Programming models: shared memory, message passing, peer-to-peer, broker-based. OpenMP and MPI. Architecture of cluster-based systems. Issues in cluster design: performance, single-system-image, fault tolerance, manageability, programmability, load balancing, security, storage. Architecture of Grid systems. Grid security infrastructure. Examples of Grids: Globus etc. Examples of representative applications. Web services, service-oriented architecture (SOA) and service component architecture (SCA). Distributed systems for large-scale data processing and analysis (Big Data). Data streams and complex event management and processing systems. Publish-subscribe systems and event notification systems. Cloud computing. Map/Reduce (Hadoop) platform for distributed massive data processing. Wireless sensor networks. Analysis, design and implementation of distributed systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Andrew S. Tanenbaum, Maarten Van Steen, Distributed Systems: Principles and Paradigms, 3 Edition, Prentice Hall, 2017		
2	George Coulouris, Jean Dollimore and Tim Kindberg, Distributed Systems: Concepts and Design, 5th Edition, Addison Wesley/Pearson Education, 2011.		
3	Nathan Marz, James Warren, Big Data: Principles and best practices of scalable realtime data systems, Manning Publications, 2015		
4	Simone Cirani, Gianluigi Ferrari, Marco Picone, Luca Veltri, Internet of Things: Architectures, Protocols and Standards, Wiley 2018.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, independent student work on projects, student seminars.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	40
Colloquia	40		
Projects	20		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Future Internet		
Lecturer (for lectures)	Tošić B. Milorad, Petković M. Ivan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introducing students to the European research agenda on new Internet as well as with research in other parts of the world on this subject. Gaining experience in research outputs topics and issues that are relevant to the currently active projects. Practical experience with the experiments on the global development platforms for new Internet		
Course outcomes	Students are able to engage in research in any of the major European projects in the field of the new Internet. They will become familiar with the fundamental theories so that in practice can detect and solve problems, mastered the practical skills of experimentation and development solutions.		
Course outline			
Theoretical teaching	Common conceptual foundations of the new Internet: an overview of system architecture, the principle of network neutrality, socio-economic aspects, the network, security, resource management, quality of service, information facilities, the business aspect. Cognitive systems. Services as a basic building block of the new Internet: System Architecture, p-2-p services, management services. Virtualization. Overlay network. Ontologies as a building block of the new Internet: Conclusion and management system, analytics and performance measurement, recording and management of resources. New Internet Basics: architectures, mobile Internet, cloud computing, identity and trust, searching and finding, experiments. Technological aspects: Internet of Things, networks, content services. Applications: smart cities, smart energy management, smart health, smart business systems, and so on. Infrastructure development and experimental approaches. Prototype implementation.		
Practical teaching (exercises, OFE, study and research	Independent research.		
Textbooks/references			
1	Books on the Internet, material available on the internet;		
2	Testbed network and computer environments to experiment with the future Internet. Domingue, J. et. al., The Future Internet, Lecture Notes in Computer Science, Vol. 6656 2011, 465 p. ISBN 978-3-642-20897-3, Springer		
3	Domingue, J. et. al., The Future Internet, Lecture Notes in Computer Science, Vol. 6656 2011, 465 p. ISBN 978-3-642-20897-3, Springer		
4	Correia, L.M.; Abramowicz, H.; Johnsson, M.; Wünstel, K., Architecture and Design for the Future Internet, 2011, 306 p. ISBN 978-90-481-9346-2, Springer		
5	Anand R Prasad, Future Internet Services and Service Architectures, River Publishers		

Number of classes of active education per week during semester/trimester/year

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0

Teaching methods	Lectures, Auditorial exercises, Laboratory exercises; Consultations, Independent students' research; students' oral presentation to the selected / given topics; Active students' participation in the classroom using online code and documents repository available in the Laboratory.

Grade (maximum number of points 100)

Pre-exam duties	Points	Final exam	Points
Activity during lectures		Written exam	
Exercises	50	Oral exam	50
Colloquia			
Projects			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Design and Analysis of Parallel Algorithms		
Lecturer (for lectures)	Milovanović I. Emina, Milovanović Ž. Igor		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	This course explores the principles and practise of parallel of parallel and distributed computing.		
Course outcomes	Students should be qualified to develop and analyze parallel algorithms for various applications and further independent scientific and research work.		
Course outline			
Theoretical teaching	Principles of parallel algorithm design. Decomposition techniques. Data decomposition. Recursive decomposition. Speculative decomposition. Hybrid decomposition. Analyzing algorithms. Running time. Number of processors. Cost. Other measures. Parallel algorithms in linear algebra. Matrix-by-vector multiplication. Matrix-matrix multiplication. Solving systems of linear equations. Eigenvalue and eigen-vectors computation. □ Parallel methods in numerical analysis. Finding roots of polynomial. Integration. Interpolation. Orthogonal discrete transformations. Solving partial differential equations.□ Parallel algorithms in graph theory. Transitive closure and reduction. Paths in graph. Spanning trees. Tunnel problem. Min-cut max-flow. Greedy algorithms.		
Practical teaching (exercises, OFE, study and research	Individual research work.		
Textbooks/references			
1	Jorge Luis Ortega-Arjona, Patterns for Parallel Software Design, John Wiley & Sons, 2010.		
2	S. Akl, The design and		
3	Alexey L. Lastovetsky		
4	I. Foster, Designing and building parallel programs, Addison-Wesley, 1995.		
5	research articles		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	consultations, independent study research			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Fault Tolerant System Design		
Lecturer (for lectures)	Milentijević Z. Ivan, Milovanović I. Emina		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The main objective is to present advanced methods and techniques for fault tolerant system design.		
Course outcomes	Students are expected to deeply understand the methodology of fault tolerant system design.		
Course outline			
Theoretical teaching	Reliability, availability, security, performance, sustainability, testability. Failure and error models. Fault tolerant strategies: Fault detection, masking, containment, location, reconfiguration, and recovery. Fault Tolerant Design. Modular redundancy and reconfiguration. Partial fault-tolerance, acceptable performance degradation, functional and logical degradation. Design of self checking circuits. Design of checkers using m-out of 'n' codes, Berger codes and low cost residue code.		
Practical teaching (exercises, OFE, study and research	individual research		
Textbooks/references			
1	I. Koren and C. Krishna, "Fault-Tolerant Systems", Morgan Kaufmann, San Francisco, US, March 2007.		
2	E. Dubrova, Fault-Tolerant Design, Springer-Verlag New York, 2013.		
3	Selected scientific papers		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Consultations, research projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Bioinformatics		
Lecturer (for lectures)	Tošić B. Milorad, Nejković M. Valentina		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Students will understand the role of information technologies in the usage of bioinformatics and opportunities for professional and scientific-research career in this field.		
Course outcomes	Ability to understand problems in the field of bioinformatics, professional and scientific literature retrival from this area, knowledge of existing publicly available data sources, and adopting the vocabulary and terminology in this field. Students are able to develop software tools for access to publicly available databases and to manipulate data that way obtained. The development of new algorithms and software solutions in bioinformatics.		
Course outline			
Theoretical teaching	Selected topics of bioinformatics and proteomics. Fundamentals: Genetics, Proteomics, Chemistry, Biology. Selected algorithms used in bioinformatics applications, current real-world examples, actual implementations, and engineering design issues. Developing software in bioinformatics: overview of existing bioinformatics resources available in public, developing software for existing databanks, software architectures for archiving data, algorithms for search and information extraction. The use of data warehouses, databases, and ontologies in the bioinformatics community.		
Practical teaching (exercises, OFE, study and research	Lectures, Consultations, Independent students' research; students' oral presentation to the selected / given topics; Active students' participation using online code and documents repository available in the Laboratory.		
Textbooks/references			
1	Robinson, Peter N., and Sebastian Bauer. Introduction to bio-ontologies. Chapman and Hall/CRC, 2011.		
2	Mount, David W., and David W. Mount. Bioinformatics: sequence and genome analysis. Vol. 2. New York:: Cold spring harbor laboratory press, 2001.		
3	Xiong, Jin. Essential bioinformatics. Cambridge University Press, 2006.		
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, exercises, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	50	**Oral exam**	50
Colloquia			
Projects			

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Medical Informatics		
Lecturer (for lectures)		Janković S. Dragan, Rajković J. Petar		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Introducing students to the field of medical informatics and focusing on the reasons and the benefits of applying information and communication technologies along with corresponding statuses and perspectives.			
Course outcomes	The students should get the knowledge of the current state and future trends in medical informatics. They should develop the skills to critically examine benefits and disadvantages of applying different software solutions in medicine.			
Course outline				
Theoretical teaching	The definition of medical informatics. The importance and the role of medical informatics (quality, security, price, efficiency, research methods). Medical informatics and bioinformatics. Biomedical informatics. telemedicine. Medical information systems. Laboratory information systems. Clinical information systems. Telemedicine. Telediagnostics. The classes of information. Electronic patient record. Web based MIS. Interoperable MIS. Data and knowledge mining. Expert systems as a part of a MIS. Decision support systems. Data privacy and security. Medical data transfer standards. Medical imaging. DICOM. PACS. Data compression. Statistical data analysis. Data management and distribution. Data warehousing. Informational support for clinical researches.			
Practical teaching (exercises, OFE, study and research	The topics presented on the auditive and laboratory exercises follow material presented during lectures. The exercises are envisioned as a basis for the individual student projects development.			
Textbooks/references				
1	Shortliffe, Edward H. Biomedical informatics. Ed. James J. Cimino. Springer Science+ Business Media, LLC, 2006.			
2	Blum, Bruce I. Clinical information systems. Springer-Verlag, 2013.			
3	J.H. van Bemmel, M.A. Musen, Handbook of medical Informatics, Sprnger Verlag, 1997.			
4	Coiera, Enrico. Guide to health informatics. CRC press, 2015.			
5	Lectures in a form of Power Point Presentations			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, independent student work on projects, student seminars			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Applications of Spectral Techniques for Digital Devices Design		
Lecturer (for lectures)	Stojković R. Suzana		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Expose the necessary theoretical background for the consideration of spectral techniques and methods for the design of digital devices (software and hardware) using spectral techniques.		
Course outcomes	Students will be able to successfully and independently apply spectral methods in the analysis, design and testing of digital devices.		
Course outline			
Theoretical teaching	Mathematical fundaments for the consideration of spectral techniques in the design of digital devices. Spectral representations of discrete functions, functional development at the level of bits and words, and corresponding decision diagrams. Methods for efficient calculations of the spectral transformations, special emphasis on calculation by decision diagrams. Methods for calculation of autocorrelation functions and their application in this field. Analysis and synthesis of logic functions (binary and multiple-valued) by logic networks using spectral techniques. Spectral methods for the synthesis of sequential networks with emphasis on the problems of coding. Analysis autocorrection features and reliable design of digital systems using spectral techniques. Spectral methods for testing of digital systems.		
Practical teaching (exercises, OFE, study and research	Independent research.□		
Textbooks/references			
1	Karpovsky, M.G., Stankovic, R.S., Astola, J.T., Spectral Logic for Design of Digital Devices, Wiley		
2	T. Sasao, M. Fujita (eds.) Representations of Discrete Functions, Kluwer, 1996.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Seminars, consultations			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Mobile and Ubiquitous Computing		
Lecturer (for lectures)	Stojanović H. Dragan, Predić B. Bratislav		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring scientific, theoretical and practical knowledge in mobile and ubiquitous computing, particularly methods, technologies and platforms for development of mobile and ubiquitous systems, applications and services.		
Course outcomes	Scientific and professional knowledge on principles, methods, technologies and platforms for development of mobile and ubiquitous systems, applications and services in mobile and ubiquitous computing.		
Course outline			
Theoretical teaching	Introduction to mobile and ubiquitous computing. Mobile and ubiquitous computer devices: smart phones, smart embedded devices, wearable computers, Internet of Things. Advanced wireless networks and wireless protocols. Methods and systems for acquisition, processing and analysis of mobile device sensors data. Advanced technologies and systems for mobile positioning and location based services. Sensing and acquisition of context in mobile and ubiquitous computing. Wireless sensor network platforms and systems. Data management in mobile and ubiquitous computing and Internet of Things. Architecture, design and implementation of mobile and ubiquitous applications and services. Human, mobile computer and ubiquitous computing environment interaction. Privacy and security in mobile and ubiquitous computing. Advanced applications: smart homes, ubiquitous healthcare, intelligent transportation systems, location-based and context-aware services.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Laurence T. Yang, Evi Syukur, Seng Loke, Handbook on Mobile and Ubiquitous Computing, CRC Press, 2016		
2	Perry Lea, Internet of Things for Architects, Packt Publishing, 2018		
3	John Krum (Ed.): Ubiquitous Computing Fundamentals. CRC Press, October 2009.		
4			
5			

Number of classes of active education per week during semester/trimester/year

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0

Teaching methods	Lectures, independent student work on projects, student seminars.

Grade (maximum number of points 100)

Pre-exam duties	Points	Final exam	Points
Activity during lectures		Written exam	
Exercises		Oral exam	40
Colloquia	40		
Projects	20		

Specification for the book of courses

Study program			Electrical Engineering and Computer Science	
Module			Common	
Type and level of studies			Doctoral studies	
The name of the course			Advanced Topics in Computer Graphics	
Lecturer (for lectures)			Rančić D. Dejan, Milosavljević Lj. Aleksandar, Dimitrijević M. Aleksandar	
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Disseminating students' knowledge in the field of computer graphics and getting acquainted with advanced techniques and algorithms, as well as with current research in this field.			
Course outcomes	Getting to know advanced techniques and computer graphics algorithms. Getting to know the latest trends in computer graphics. Competence for independent scientific research in the field of computer graphics. Ability to independently program complex graphic applications using modern concepts in this field.			
Course outline				
Theoretical teaching	Advanced rendering and animation techniques. Volume visualization. Modeling and visualization of natural phenomena. Fluid visualization (smoke, fire, liquid). Modeling and visualization of the terrain. Molecular graphics. Fractals and chaos. Advanced Virtual Reality Techniques. Efficiency and complexity of computer graphics algorithms. Object-oriented graphics. Graphics and human perception.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	P. Shirley, S. Marschner, Fundamentals of Computer Graphics, 3rd ed., CRC Press, 2009.			
2	J. Foley, A. van Dam, S. Feiner, J. Huges, Computer Graphics Principles and Practice, 2nd ed. in C, Addison-Wesley, 1996.			
3	E. Angel, D. Shreiner, Interactive Computer Graphics A Top Down Approach with Shader-based OpenGL, 6th ed., Addison-Wesley, 2012.			
4	J. Vince, Mathematics for Computer Graphics, 2nd ed., Springer, 2006.			
5	P. Carvalho, L. de Figueiredo, J. Gomes, L. Velho, Mathematical Optimization in Computer Graphics and Vision, Elsevier, 2008.			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations, independent study research.			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures			**Written exam**	
Exercises			**Oral exam**	50
Colloquia				
Projects		50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topic in Intelligent Systems		
Lecturer (for lectures)	Stoimenov V. Leonid, Tošić B. Milorad, Stanimirović S. Aleksandar		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring scientific, theoretical and practical knowledge in artificial intelligence domain and realization of intelligent systems, particularly methods, technologies and platforms for design and development of intelligent systems, data mining and colaborative systems.		
Course outcomes	Students will be able to recognize current problems in this area, and potential ones solutions. He will be able to apply some of the suggested methods and techniques and be trained to critically approach their evaluation. Students will be trained for research in the domain of current theoretical topics.		
Course outline			
Theoretical teaching	Intelligent Systems - Overview and Architecture. Artificial Intelligence as a basis for the Implementation of Intelligent Systems. Autonomous inference. Intelligent Agents. Architectures that include perception, learning, knowledge presentation, conclusion and reactions.Characteristics of Machine Learning: Combining different types of knowledge in agents (e.g. using reliability models based on probability, knowledge acquired and knowledge management). Coordination and collaboration among agents. Machine learning and processing and analysis of existing data. Knowledge and Understanding: Ontology and semantics. Languages for representation of ontologies. Ambient intelligence. General conceptual assumptions, strategy domains, business aspects, mathematical basics, and some sociological basics of intelligent systems. Information systems, Internet, social networks and artificial intelligence systems for the processing and analysis of such data. Analysis of data from Big data system and systems with large amount of data. Realization of "smart" systems, integration with sensors and devices from the environment, Internet of things and artificial intelligence.		
Practical teaching (exercises, OFE, study and research	Practical implementation and intelligent systems implementation based on existing open source libraries. Designing and developing classic systems that include intelligent modules / systems.		
Textbooks/references			
1	S. Russel, P. Norvig, Artificial intelligence - A Modern Approach, Pearson, 3rd edition, (2016), ISBN-10: 1292153962, ISBN-13: 978-1292153964		
2	J.Han, M. Kamber, J. Pei, Data Mining: Concepts and Techniques, The Morgan Kaufmann Series in Data Management Systems, 3rd Edition, (2011), ISBN-10: 9780123814791, ISBN-13: 978-9380931913		
3	Erl, Khattak & Buhler, Big Data Fundamentals: Concepts, Drivers & Techniques (2016), Prentice Hall, ISBN-13: 9780134291079		
4	G. Hulten, Building Intelligent Systems: A Guide to Machine Learning Engineering, 1st ed. edition (2018), ISBN-10: 1484234316, ISBN-13: 978-1484234310		
5	C. Sammut (Editor), G. I. Webb (Editor), Encyclopedia of Machine Learning and Data Mining, Springer, 2nd ed. (2017), ISBN-10: 148997685X, ISBN-13: 978-1489976857		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	The course consists of lectures, student presentations, homework and projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Topics in Specialized Information Systems		
Lecturer (for lectures)	Stojanović H. Dragan, Janković S. Dragan, Rančić D. Dejan, Predić B. Bratislav		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring scientific, theoretical and practical knowledge in specialized information system domain, particularly methods, technologies and platforms for design and development of such systems.		
Course outcomes	Scientific and professional knowledge on principles, methods, technologies and platforms for development of specialized information systems.		
Course outline			
Theoretical teaching	Special purpose information systems with service-oriented architecture, based on advanced technologies. Distributed and peer-to-peer information systems. Mobile and ubiquitous information systems. Geographic, multimedia, medical, business, transport and intelligent information systems. Command and control information systems. Information systems based on large-scale data processing and analysis. Information systems based on publish-subscribe principle, event-based systems as well as event notification systems. Middleware of specialized information systems: message brokers, message oriented middleware, transaction oriented middleware, application servers. Analysis, design and implementation of specialized information systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Martin Kleppmann, Designing Data-Intensive Applications, O'Reilly Media, Inc., 2017		
2	Karen A. Wager, Frances W. Lee, John P. Glaser, Health Care Information Systems: A Practical approach for Health Care Management, John Wiley, Jossey-Bass; 2 edition,2009.		
3	Ian Kemp, C4I Systems Handbook, Issue 6, The Shephard Press Ltd, 2012.		
4	Nathan Marz, James Warren: Big Data Principles and best practices of scalable realtime data systems. Manning Publications Co., 2015.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, independent student work on projects, student seminars.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	40
Colloquia	40		
Projects	20		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Mathematical Fundament of the Game Theory		
Lecturer (for lectures)	Vučković V. Vladan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Mastering the basic principles and models of mathematical game theory.		
Course outcomes	Students' competence for strategic thinking and analysis, as well as the application of methods of mathematical theory of games in solving real problems from practice.		
Course outline			
Theoretical teaching	Introduction and general principles: The subject and goal of studying the theory of games. A brief overview of the history of game theory. Basic concepts and definitions of mathematical game theory. Terminology. Classification of games. Strategic and formal thinking. The importance and definitions of the rules of the game. The notion of the Nash equilibrium. Mathematical model of the Nash equilibrium. Mathematical basis of logical games. Games with simultaneous moves (static games). Games with sequential moves (dynamic games). General classes of games and strategies: Cooperative and non-cooperative games. Characteristic games. Game of skills, game of chances, strategy games. Formal definition of games. Strategic and tactical moves. Applications of mathematical theory of games. Applications in computer logic games. Mathematical basics of logic games algorithms. Other applications.		
Practical teaching (exercises, OFE, study and research	Preparation of seminar papers. Modeling and programming the mathematical principles of game theory. Study research. Game of skills, game of chances, game strategies - mathematical models and software realization. Analogy of characteristic games with real situations through examples. Software for mathematical modeling and simulation of static and dynamic games. Software and examples of logical games.		
Textbooks/references			
1	Dixit A., and Skeath S., Games of Strategy, 2nd edition, Norton, New York, 2004.		
2	Vladan Vučković, "Contribution to the theory and practice of advanced chess algorithms", Doctoral dissertation, Faculty of Electronic Engineering in Niš, October 2006.		
3	www.gametheory.net		
4	Vladan Vučković "Advanced chess algorithms and systems", monograph, Endowment Andrejević, Biblioteka Dissertatio, Belgrade 2011, ISSN 0354-7671.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, consultations, seminar papers, study research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program			Electrical Engineering and Computer Science	
Module			Common	
Type and level of studies			Doctoral studies	
The name of the course			Advanced Topics in E-Learning Technologies	
Lecturer (for lectures)			Milentijević Z. Ivan, Stoimenov V. Leonid, Rančić D. Dejan, Janković S. Dragan	
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS		10	**Course status (obligatory/elective)**	Elective
Prerequisites				
Course objectives	To familiarize students with: current trends in learning support technologies, evaluation methods and development of advanced learning support tools.			
Course outcomes	After the course students will be prepared to apply advanced methods, principles and tools for the evaluation of learning support technologies. Students will be prepared for research in the field of development of learning support resources.			
Course outline				
Theoretical teaching	Research work on the upgrading of existing and development of new IT resources for learning support. HCI in learning. Customization of general purpose software tools for learning support. The development of new tools to support collaborative learning, and computer aided testing. Methods, techniques and tools for evaluation of learning support software (evaluation in terms of technical and educational quality).			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	Advanced Methodologies and Technologies in Modern Education Delivery, Mehdi Khosrow-Pour (Ed.), IGI Global, 2018.			
2	M. S. Khine, I. M. Saleh, New Science of Learning: Cognition, Computers and Collaboration in Education, Springer, 2010.			
3	Ennio Cipani, Practical Research Methods for Educators, Springer, 2009.			
4	E-Learning Paradigms and Applications, Ivanović M., Jain L. (Eds.), Springer, 2013.			
5	Collection of selected scientific papers			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, guided discussion, projects.			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures			**Written exam**	
Exercises			**Oral exam**	50
Colloquia				
Projects		50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Web Mining and Information Retrieval		
Lecturer (for lectures)	Stojković R. Suzana, Bogdanović D. Miloš		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	This course should enable students acquire advanced knowledge of the techniques and algorithms used in the search, classification and clustering of Web documents and the possibilities of their application in practical implementations. This course should prepare students for independent research work in the field of Web mining and information retrieval		
Course outcomes	Acquired knowledge regarding advanced techniques used for analyzing the content of Web documents, analyzing the structure of the Web, analyzing the usage of the Web, as well as algorithms and techniques used within recommendations systems. Students should be capable of developing projects based on the application of Web mining techniques and information retrieval.		
Course outline			
Theoretical teaching	Overview of the basic problems in the field of Web mining. Taxonomy of the Web. Analysis of the content of Web documents. Customizing Machine Learning techniques to Web document analysis. Ranking and automatic evaluation of documents. Sentiment analysis. Web structure analysis. Detect user behavior patterns. Tools used to analyze the Web and its application. Examples of projects based on the application of Web mining techniques.		
Practical teaching (exercises, OFE, study and research	Independent research work, seminar papers and projects.		
Textbooks/references			
1	S. Chakrabarti: Mining the Web: Discovering Knowledge from Hypertext Data, Morgan Kaufmann, 2002.		
2	B. Liu: Sentiment Analysis: Mining Opinions, Sentiments, and Emotions, Cambridge University Press, 2015		
3	Charu C. Aggarwal: Recommender Systems: The Textbook, Springer, 2016.		
4	C. D. Manning, P. Raghavan, H. Schutze: An Introduction to Information Retrieval, Cambridge University Press, Cambridge, England, 2009.		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations of specific topics, seminars and projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Modelling and Design of Microwave Devices and Systems		
Lecturer (for lectures)		Dončov S. Nebojša, Marinković D. Zlatica		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	The acquisition of higher level theoretical and practical knowledge in the field of modeling and design of microwave devices and systems.			
Course outcomes	Ability to independently solve complex problems in the field of modeling and design of microwave devices and systems.			
Course outline				
Theoretical teaching	Field theory. Numerical methods in applied electromagnetics. Guided electromagnetic waves. Application of circuits theory methods in the RF and microwave frequency range. Modeling of electromagnetic fields. Analysis and optimization of microwave circuits. Modeling and design of devices and systems in various areas of telecommunications.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	D. Pozar, Microwave Engineering, John Wiley & Sons, Inc., 1997.			
2	W. Egan, Practical RF System Design, John Wiley & Sons, Inc., 2000.			
3	S E. Wolff, R. Kaul, Microwave Engineering and System Applications, John Wiley & Sons, Inc., 1988.			
4	E. Yamashita, Analysis Methods for Electromagnetic Wave Problems, Artech House, 1990.			
5	C. Christodoulou, M. Gergiopoulos, Applications of Neural Networks in Electromagnetics, Artech House , 2001.			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, simulations on computer, consultations, seminar paper.			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures			**Written exam**	
Exercises			**Oral exam**	50
Colloquia				
Projects		50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Error Control Coding Techniques		
Lecturer (for lectures)	Jovanović Ž. Aleksandra		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Disseminating knowledge and getting acquainted with the latest achievements and research in the field of the error control coding, with a special emphasis on the advanced iterative decoding algorithms.		
Course outcomes	The student will fully understand the complex iterative decoding algorithms and will be able to implement them. The student will acquire knowledge that will enable him to follow professional literature and to engage in scientific research in the field of error control coding.		
Course outline			
Theoretical teaching	Error correction codes in modern communication systems and storage systems. Trellis-based decoders. Viterbi algorithm. SOVA algorithm. BCJR algorithm. Iterative decoding of codes on graphs (LDPC codes). Bit-flipping algorithm. Message passing algorithm and turbo principle. Sum-product algorithm. Min-sum algorithm. Gallager A and B algorithms.		
Practical teaching (exercises, OFE, study and research	Project assignments.		
Textbooks/references			
1	W. E. Ryan, S. Lin, Channel Codes - Classical and Modern, Cambridge University Press, 2009.		
2	Silvio A. Abrantes, From BCJR to turbo decoding: MAP algorithms made easier, https://paginas.fe.up.pt/~sam/textos/From%20BCJR%20to%20turbo.pdf		
3	R. G. Gallager, Low Density Parity Check Codes, https://web.stanford.edu/class/ee388/papers/ldpc.pdf		
4	T. Richardson, R. Urbanke, Modern Coding Theory, Cambridge University Press, Cambridge, 2008.		
5	S. Lin, D. J. Costello, Error Control Coding, Pearson, 2004.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations. Scientific research.□			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	10	**Written exam**	
Exercises		**Oral exam**	40
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Microwave Electronics		
Lecturer (for lectures)	Pronić-Rančić R. Olivera, Maleš-Ilić P. Nataša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the advanced techniques of design and optimization of linear and nonlinear microwave circuits.		
Course outcomes	Understanding the principles of operation and ability to design microwave electronic circuits.		
Course outline			
Theoretical teaching	Modern CAD techniques - modeling, simulation and optimization of microwave circuits. Microwave semiconductor devices: microwave diodes and transistors. Applications of microwave semiconductor devices. RF and microwave amplifiers. Small signal amplifiers and nonlinear amplifiers. Low-noise amplifiers. Broadband amplifiers. Power amplifiers - basic features and applications. Classes of power amplifiers. Harmonic balance analysis. RF and microwave oscillators. Mixers. Detectors. Modulators. Microwave control circuits (switches, phase shifters, limiters, attenuators). Microwave integrated circuits.		
Practical teaching (exercises, OFE, study and research	Solving selected problems in the form of seminar papers. Analysis and optimization of microwave circuits and components using specialized software packages.		
Textbooks/references			
1	I.A. Glover, S.R. Pennock, P.R. Shepherd, Microwave devices, circuits and subsystems for communications engineering, John Wiley & Sons Inc.,2005.		
2	R. Gilmore and L. Besser, Practical RF Circuit Design for Modern Wireless Systems, Volume II: Active Circuits and Systems, Norwood: Artech House, 2003.		
3	D. Pozar, "Microwave Engineering - third edition", John Wiley & Sons, Inc., 2005.		
4	I. Bahl, P. Bartia, "Microwave Solid State Circuit Design", John Wiley & Sons, Inc., 2003.		
5	O. Pronić, V. Marković, N. Maleš – Ilić, B. Milovanović: "Microwave electronics (in Serbian)", Faculty of electronic engineering, Niš, 2013.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Seminar papers. Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Wireless Communications		
Lecturer (for lectures)		Marković V. Vera, Stanković Ž. Zoran		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Deepening of knowledge related to the concept, architecture and functioning of modern wireless communication systems and learning about methods for solving problems in selected areas.			
Course outcomes	Knowledge of the important aspects of modern wireless communications. Ability to apply specific techniques, methods, and models for analyzing and/or designing in the field of wireless communication systems.			
Course outline				
Theoretical teaching	Overview of microwave wireless communication systems. Advanced wireless services. Propagation models in the RF and microwave frequency range. Selected topics in the field of fixed and mobile communication systems. Wireless communication systems architecture and design of RF components and subsystems for wireless communications. Methods for the characterization of non-ionizing radiation levels of wireless systems and the biological effects of radiation.			
Practical teaching (exercises, OFE, study and research	Insight into selected literature. Examining a specific problem. Independent research work.			
Textbooks/references				
1	D.P.Agrawal, Q.A.Zeng, Introduction to Wireless and Mobile Systems, Thomson, 2006			
2	T. Novosad, Radio Network Planning and Optimisation for UMTS, John Wiley &Sons, 2006			
3	A. Osseiran, J. Monserrat, P. Marsch, 5G Mobile and Wireless Communications Technology, Cambridge University Press, 2016.			
4	Selected scientific publications			
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations, seminar work and students' projects			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	CDMA and OFDM Communications		
Lecturer (for lectures)	Nikolić B. Zorica		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Getting to know the characteristics and methods of forming and OFDM and code multiplex. Introduction to the problems of synchronization of these systems and ways of overcoming them. Mastering the technique of determining capacity. Introduction to standards.		
Course outcomes	Theoretical knowledge of OFDM and code multiplex. The ability to calculate system performance. Knowledge of CDMA and OFDM systems standards.		
Course outline			
Theoretical teaching	CDMA Transmission ChannelModels. Representation of CDMA signals. The discrete channel model for synchronous transmission in a frequency-flat channel. The discrete channel model for asynchronous wideband CDMA transmission. Receiver Structures for Synchronous Transmission The single-user matched filter receiver. Optimal receiver structures . Receiver Structures for MC-CDMA and Asynchronous Wideband CDMA. The RAKE receiver . Examples for CDMA Systems: Wireless LANs according to IEEE 802.11 , Global Positioning System, Overview of mobile communication systems , Wideband CDMA, Time Division CDMA, cdmaOne ,cdma2000. Implementation and Signal Processing Aspects for OFDM. Synchronization and Channel Estimation Aspects for OFDM Systems. Interleaving and Channel Diversity for OFDM Systems Modulation and Channel Coding for OFDM Systems.OFDM System Examples.		
Practical teaching (exercises, OFE, study and research	Students work independently on the project (project presentation with discussion).		
Textbooks/references			
1	H. Anderson:Fixed Broadband Wireless: System Design, John Wiley&Sons, LTD, 2003.		
2	T. Rappaport : Wireless Communications – Principles & Practice, Prentice Hall, 2002		
3	Z. Nikolic: Spread spectrum systems performance (in Serbian), Faculty of Electronic Engineering Niš, 2006, Edition: Monographs		
4	Z. Nikolic, N. Milosevic, B. Dimitrijevic: Multiplex signal transmission (in Serbian), Faculty of Electronic Engineering Niš, 2006, Edition: textbooks		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Giving lectures. Students work independently on the project (project presentation with discussion).			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Telecommunications Theory		
Lecturer (for lectures)	Đorđević T. Goran, Milović M. Daniela		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The acquisition of knowledge from Theory of Telecommunications and their application for the analysis, design and optimization of modern wireless and optical systems. Training for independent research work in this field.		
Course outcomes	After passing the exam students will: 1) know that they apply acquired knowledge and skills from Theory of Telecommunications in the study of modern optical and wireless systems; 2) know how to determine the limits that can improve the performance of these systems; 3) know how to analyze and project receivers in channels with intersymbol interference using analytical and simulation methods.		
Course outline			
Theoretical teaching	Statistical characterization of channels in modern radio-frequency and optical wireless systems. Error probability and capacity evaluation using analytical and simulation approach. Controlled intersymbol interference. Optimal detection in different channel conditions. Combined equalization and coding. Spatial-time codes. Performance assessment of multi-cell wireless systems. Study the information transmission through Visible Light Communications - VLC from the point of view of Theory of Telecommunications.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	A. Papoulis, S. U. Pillai, Probability, random variables and stochastic processes, 4th edition, McGraw-Hill Europe, 2002.		
2	E. Biglieri, Coding for Wireless Channels, Springer, 2005.		
3	Z. Ghassemlooy, W. Popoola, S. Rajbhandari, Optical Wireless Communications: System and Channel Modelling with MATLAB, CRC Press, 2017.		
4	D. B. Drajić, Introduction to Statistical Telecommunications Theory (in Serbian), Akademska misao, Belgrade, 2006.		
5	T. Richardson and R. Urbanke, Modern Coding Theory, Cambridge Univ Press, 2008.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	20
Exercises		**Oral exam**	30
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Modulation Techniques		
Lecturer (for lectures)	Milić N. Dejan, Nikolić B. Zorica		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering the basic knowledge necessary to determine the performance of digital modulation techniques.		
Course outcomes	Theoretical knowledge; Mastering the use of appropriate software simulation		
Course outline			
Theoretical teaching	Minimum Shift Keying (MSK) and MSK modulation types. Modulation with the continuous phase. Phase Modulation. Spectrally efficient modulation without constant envelope. Performance of modulation techniques in fading channels, and equalization.		
Practical teaching (exercises, OFE, study and research	Theorecical lectures, consultations, research work		
Textbooks/references			
1	G.Lukatela, D.Drajić, G.Petrović, R.Petrović: "Digital Telecommunications" (in Serbian), Građevinska knjiga, Beograd, 1984.		
2	T.Oberg: "Modulation, Detection and Coding", John Wiley, 2001.		
3	F.Xiong: "Digital Modulation Techniques", Second Edition, Artech House, 2006.		
4	J. G. Proakis, "Digital communications", fourth edition, McGraw Hill, 2001.		
5			

Number of classes of active education per week during semester/trimester/year

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0

Teaching methods	Lectures; Consultations; Study and research work.

Grade (maximum number of points 100)

Pre-exam duties	Points	Final exam	Points
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Telecommunications		
Lecturer (for lectures)	Perić H. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring theoretical knowledge, getting acquainted with the latest achievements and research in the field of digital telecommunications		
Course outcomes	Extended theoretical knowledge in the field of digital telecommunications. Ability to solve problems in the study area.		
Course outline			
Theoretical teaching	Adaptive scalar quantization. Adaptive Pulse-code modulation. Adaptive differential Pulse-code modulation. Adaptive Delta modulation. Coding with delayed decision making. Subband coding. Channel capacity and coding. Channel coding. Scalar and vector quantization. Transform coding. Audio and speech signal compression. Video signal compression.		
Practical teaching (exercises, OFE, study and research	Lectures.Consultations.Study and research work.		
Textbooks/references			
1	Z. Perić, Osnove vektorske kvantizacije, monografija, Elektronski fakultet u Nišu, 2005		
2	J. Proakis, M. Salehi, Digital Communications, McGraw-Hill Education, 5th edition, 2007.		
3	N.S. Jayant, P. Noll, Digital Coding of Waveforms, Prentice-Hall, New Jersey, 1984.Publishers, 1992.		
4	M.Safak, Digital Communications,Wiley, 1st edition, 2017		
5	Z. Perić, A. Jovanović, Geometrijska vektorska kvantizacija, monografija, Elektronski fakultet u Nišu, 2010.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Project work. Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Signal Processing		
Lecturer (for lectures)	Perić H. Zoran, Dončov S. Nebojša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring theoretical knowledge, introduction to the latest achievements and research in the field of digital signal processing.		
Course outcomes	Expanded theoretical knowledge from the field of digital signal processing. Ability for solving problems from the studied field.		
Course outline			
Theoretical teaching	Discrete signals and systems. Discrete direct and inverse Fourier transform. Algorithms of direct and inverse fast Fourier transform. Direct and inverse z-transform. Discrete transfer functions. Discrete transforms (DCT, DFT, DWT). Digital recursive and nonrecursive filters and their realisations. Wave digital filters and realisations. Frequency and time analysis. Appliance of digital filters in the construction of linear predictors, both fixed and adaptive. Estimation of discrete signal's parameters. Digital signal processing in frequency domain. Basics of digital signal processing needed for subsegment coding (filter banks). Digital signal processors for filter realisations. Software package for digital signal processing MATLAB.		
Practical teaching (exercises, OFE, study and research	Lectures. Consultations. Work on project.		
Textbooks/references			
1	Nader Hamdy, Applied Signal Pocessing, CRC Press 2009		
2	M. V. Popovic, Digital Signal Processing (in Serbian), Science, Belgrade, 1994		
3	Lj. Stanković, Digital Signal Processing with Selected Topics: Adaptive Systems Time Frequency Analysis Sparse Signal Processing, Create Space Independent Publishing Platform, 2015.		
4	M.Vetterli,ˈJ. Kovacevic,ˈV. K. Goyal, Foundations of Signal Processing, Cambridge University Press, 2014.		
5	D. G. Manolakis, V. K. Ingle, Applied Digital Signal Processing: Theory and Practice Cambridge University Press; 1st edition, 2011.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, project, consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Sound Generation and Perception		
Lecturer (for lectures)	Ćirić G. Dejan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering knowledge about sound, familiarizing with the newest achievements and research in sound generating, transmission, modeling and processing, as well as sound perception.		
Course outcomes	Theoretical knowledge. Solving practical problems: acoustical design, noise (sound) protection, system design, measurements, sound acquisition. Proper use of equipment. Application of knowledge in real situations such as industrial applications.		
Course outline			
Theoretical teaching	Generating speech and music signals, as well as measurement acoustical signals. Sound transmission indoors and outdoors. Sound perception. Sound acquisition (acoustical sensors). Design and analysis of modern devices for sound recording and reproduction. Acoustics of enclosed spaces. Sound reinforcement. Noise as unwanted sound and adequate protection. Creating sound effects with predefined characteristics. Standards and norms of acoustic quality. Acoustic measurement techniques. The application of technology based on sound in the industry.		
Practical teaching (exercises, OFE, study and research	Problem solving through students' reasearch projects (Sound generating (speech and music signals). Sound sources. Sound transmission. Sound perception (formation of the sound image). Acquisition of sound (analog and digital sensors, spatial dimension). Characteristics of modern devices for sound recording and sound reproduction. Acoustical characteristics of enclosed spaces. Characteristics of speech and music. Acoustical measurement techniques).		
Textbooks/references			
1	T. D. Rossing: Springer handbook of acoustics, Springer, New York, 2007.		
2	L. E. Kinsler, A. R. Frey, A. B. Coppens, J. V. Sanders: Fundamentals of acoustics, 4th edition, John Wiley & Sons, New York, 2000.		
3	H. Kuttruff: Acoustics – an introduction, Taylor & Francis, London, 2007.		
4	D. R. Raichel: The science and applications of acoustics, 2nd edition, Springer, New York, 2006.		
5	J. Blauert: Communication acoustics, Springer, Berlin, 2005.		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations. Student research projects.			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	30	**Oral exam**	40
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Compressive Sensing with Applications		
Lecturer (for lectures)	Nikolić R. Jelena		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Providing knowledge about compressive sensing of analog signals, sparse representation of signals and sparse signal coding. Training students to write scientific papers in this very current field of research.		
Course outcomes	Students first acquire knowledge about modern approaches in data acquisition, compressive sensing of analog signals, sparse representation of signals and sparse signal coding, and also about challenges that this field of research carries and sets, and then apply these knowledge through scientific research in the A / D conversion of different signals.		
Course outline			
Theoretical teaching	Modern approaches to data acquisition. Significance of compressive sensing of analog signals and a sparse representation of signals. Mathematical formulation of compressive sensing. Required conditions for sucessfull application of compressive sensing- RIP, SPARK and MIP. The problem of convex optimization in compressive sensing. Minimization of vector norms l0, l1 and l2. Deterministic approach in constructing the measurement matrice. Probabilistic approach in constructing the measurement matrice. Sparse representations of signals for the reconstruction of information from incomplete data. Sparse signal coding. Compressive sensing for a predefined dictionary. Greedy algorithms and algorithms with a relaxed condition of sparsity. Orthogonal matching pursuit algorithm. Matching pursuit algorithm. Weak matching pursuit algorithm. Analysis of the obtained approximations. Dictionary learning. Application of compressive sensing algorithms in A / D conversion of variety of signals, also in MRI algorithms and face recognition.		
Practical teaching (exercises, OFE, study and research	Lectures.Consultations. Project work.		
Textbooks/references			
1	Y. C. Eldar, G. Kutyniok, Compressed Sensing: Theory and Applications, Cambridge University Press, 2012.		
2	Y. C. Eldar, Sampling Theory: Beyond Bandlimited Systems, Cambridge University Press, 2015.		
3	M. Elad, Sparse and Redundant Representations: From Theory to Applications in Signal and Image Processing, Springer, 2010.		
4	I. Rish, G. Grabarnik, Sparse Modeling: Theory, Algorithms, and Applications, CRC Press, 2014.		
5	S. Stanković, I. Orović, E. Sejdić, Multimedia Signals and Systems: Basic and Advanced Algorithms for Signal Processing, Springer, 2016.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, Power Point presentations, Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	5	**Written exam**	
Exercises	30	**Oral exam**	35
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Audio Communications		
Lecturer (for lectures)	Ćirić G. Dejan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering knowledge, introduction to modern achievements and research within the field of audio communications, audio signals, analysis and synthesis of auditory scenes, audio analytics as well as audio signal processing.		
Course outcomes	Theoretical knowledge. Solving practical problems in the field of audio signals and systems: analysis, synthesis and design. Skills of appropriate use of audio devices and systems. Mastering the applications of modern technologies based on sound.		
Course outline			
Theoretical teaching	Audio signals (definitions, concepts). Characteristics of speech and music signals. Audio communication systems (structure and characteristics). Input and output acoustical environment (sound sources and receivers, spatial environment). Audio devices. Audio analytics. Auditory scenes (analysis and synthesis). Detection and classification of audio events. Audio signal processing. Sound synthesis. Subjective effects of sound. Spatial sound image and 3D sound. Auditory virtual environments. Audio restoration. Perceptual coding and audio compression. Sound sources separation and speech dereverberation. Analysis and processing of speech. Audio signal quality (speech quality - intelligibility). Audiometry and audiology. Hearing aids. Applications of sound based technology in medicine.		
Practical teaching (exercises, OFE, study and research	Solving problems through the students' research projects from the following teaching units: audio communication systems; effects of input and output acoustical environment; auditory scenes and virtual spaces; audio signal processing; sound synthesis; subjective effects of sound; spatial sound image; audio signal quality estimation; audio event detection; audiometry and audiology.		
Textbooks/references			
1	Y. Huang, J. Benesty: Audio signal processing for next-generation multimedia communication systems, Kluwer Academic Publishers, Boston, 2004.		
2	M. Kahrs, K. Brandenburg: Applications of digital signal processing to audio and acoustics, Kluwer Academic Publishers, USA, 2002.		
3	A. R. Moller: Hearing: anatomy, physiology, and disorders of the auditory system, 2nd edition, Academic Press, San Diego, 2006.		
4	S. Savage: The art of digital audio recording, Oxford University Press, New York, 2011.		
5	D. Jarrett, E. Habets, P. Naylor: Theory and applications of spherical microphone array processing, Springer, Switzerland, 2017.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations. Student research projects.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	30	**Oral exam**	40
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Antennas and Propagation		
Lecturer (for lectures)	Dončov S. Nebojša, Stanković Ž. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The acquisition of high-level theoretical and practical knowledge of radiation and reception of electromagnetic waves using antennas and antenna systems and electromagnetic waves propagation over the surface of the Earth.		
Course outcomes	Independently solving practical problems in the area of the design of antennas and antenna systems. Independently solving practical problems in the area of electromagnetic wave propagation modeling in real conditions over the surface of the Earth.		
Course outline			
Theoretical teaching	Analysis of antennas and antenna arrays (analytical and numerical methods). Synthesis of antennas and antenna arrays. Software tools for analysis and synthesis of antenna, antenna arrays and antenna systems. The design procedures for different classes of antennas that have practical applications in modern wireless communication systems. Adaptive antenna structure. Advanced techniques in DOA estimation. Electromagnetic wave propagation modeling. Electromagnetic field prediction in different local-specific regions for different services. Neural models for electromagnetic field prediction. Numerical, empirical, neural and hybrid methods in electromagnetic wave propagation modeling. Implementation of local-specific neural and hybrid empirical-neural (HEN) models with increased efficiency of prediction .		
Practical teaching (exercises, OFE, study and research	Independent research work (literature reading, analysis of particular problem and realization of its solution).		
Textbooks/references			
1	M. Dragović, Antennas and propagation, 4th edition (in Serbian), Academic mind, Belgrade, 2008.		
2	C. Balanis, Antenna theory: Analysis and Design, 4rd edition, Wiley, 2016.		
3	J. Kraus, Antennas, Mc Graw Hill, 1988.		
4	W. Stutzman, G. Thiele, Antenna Theory and Design, 3rd Edition, Wiley, 2012.		
5	B. Allen, M. Ghavami, Adaptive Array Systems: fundamentals and applications, Wiley, 2005.		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Presentations for specific topics. Seminar papers and projects.			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Applications of Neural Networks in Telecommunications		
Lecturer (for lectures)	Marković V. Vera, Marinković D. Zlatica, Stanković Ž. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring the necessary knowledge needed for independent application of artificial neural networks in the field of telecommunications.		
Course outcomes	Knowledge about basic principles of neural networks. Ability to train and test neural networks and to develop models based on neural networks. Ability to apply independently the neural networks to develop solutions for particular problems in the field of telecommunications		
Course outline			
Theoretical teaching	Neuron and biological nervous system. Artificial neural networks (ANNs). Types of ANNs. Multilayer neural networks. Recurrent neural networks. Training and testing of ANNs. Models based on neural networks. Black-box neural models. Knowledge-based neural models. Hybrid empirical-neural models. Analysis of various examples of ANN applications in the field of telecommunications. Software packages to be used for work with ANNs. Implementing neural models in specialized CAD software packages for use in telecommunications.		
Practical teaching (exercises, OFE, study and research	Independent research work (analysis of the available literature, analysis of a particular problem and finding solutions, writing and presentations of scientific work)		
Textbooks/references			
1	S. Haykin, Neural networks, New York, IEEE, 1994.		
2	Q. J. Zhang, K. C. Gupta, Neural Networks for RF and Microwave Design, Artech House, 2000.		
3	C. Christodoulou, M. Gerogiopoulos, Applications of Neural Networks in Electromagnetics, Artech House, 2001.		
4	Z. Marinković, V. Marković, A. Caddemi, "Artificial Neural Networks in Small-Signal and Noise Modeling of Microwave Transistors", Chapter 6 in „Artificial Neural Networks“ edited by Seoyun J. Kwon, Nova Science Publishers Inc., 2011, pp. 219-236		
5	Selected scientific publications		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures; independent research work; consultations. (Note: publishing a scientific paper in a journal or a presentation at a conference replaces the oral part of the exam.)			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Satellite Communication Systems		
Lecturer (for lectures)		Pronić-Rančić R. Olivera		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Introduction to the latest developments and research in the field of satellite communications systems.			
Course outcomes	Knowing principles of operation of modern satellite communication systems. Solving practical problems in the field of satellite system designing.			
Course outline				
Theoretical teaching	Configuration of a satellite communications system. Classification of satellites. Satellite orbits. Satellite hardware - satellite subsystems. Satellite link design. Modulation techniques in satellite communication systems. Multiple access techniques (FDMA, TDMA, CDMA). Earth stations. Communication satellites. Satellite telephony. Satellite television. Satellite data communication services. VSAT systems. Satellite navigation systems. GPS, GLONASS, GALILEO. Integration of GPS and geographic information systems. Remote Sensing Satellites. Weather Satellites. Military satellites.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	T. Pratt, C. Bostian, J. Allnutt, "Satellite Communications", J.Wiley & Sons, 2003.			
2	A. K. Maini, V. Agrawal, “Satellite technology – principles and applications”, Second edition, J.Wiley & Sons, 2011.			
3	G.Taylor, G. Blewitt, “Intelligent Positioning - GIS-GPS Unification”, John Wiley & Sons Ltd, 2006.			
4	G. Maral, M. Bousquet, "Satellite Communications Systems – systems, techniques and technology", fifth edition, J.Wiley & Sons, 2009.			
5	D. Minoli, “Innovations in satellite communications and satellite technology“, J. Wiley & Sons, Inc., 2015			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Projects. Consultations.			
Grade (maximum number of points 100)				
Pre-exam duties		**Points**	**Final exam**	**Points**
Activity during lectures			**Written exam**	
Exercises			**Oral exam**	50
Colloquia				
Projects		50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	RF and Microwave Amplifiers		
Lecturer (for lectures)	Maleš-Ilić P. Nataša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	Acquiring theoretical and practical knowledge in the field of RF and microwave amplifiers.		
Course outcomes	Acquire knowledge of linear and non-linear transistor models as well as transistor noise models. Introduce the structure of RF and microwave amplifiers for low-noise and high power applications. Ability to design and fabricate amplifiers.		
Course outline			
Theoretical teaching	Models of microwave transistors (MOSFET, MESFET, HEMT, BJT, HBT)-models for small signals, nonlinear models, noise modeling. Procedure of low-noise amplifier design. Power amplifiers in class-A, AB, B, C. High-efficient power amplifiers (Class-F, inverse F, D, E, J. ..). Linearization techniques. Techniques for increasing efficiency of microwave amplifiers.		
Practical teaching (exercises, OFE, study and research	Solving selected problems in the form of seminar. Analysis and optimization of RF and microwave amplifiers by using specialized software packages. Practical work in laboratory.		
Textbooks/references			
1	Steve Cripps, RF Power Amplifiers for Wireless Communications, Artech House 2006		
2	Andrei Grebennikov, RF and Microwave Power Amplifier Design, second edition, McGraw Hill, 2015		
3	Steve Cripps, Advanced Techniques in RF Power Amplifier Design, Artech House, 2002		
4	A. Grebennikov, Nathan O. Sokal, Switchmode RF Power Amplifiers, Elsevier Inc., 2012		
5	Guillermo Gonzalez, Microwave Transistor Amplifier: Analysis and Design, 2nd edition, Prentice Hall, 1997		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Auditory exercises. Practical work in laboratory. Homework. Consultations.			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises	30	**Oral exam**	50
Colloquia			
Projects	20		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Electromagnetic Compatibility and Signal Integrity		
Lecturer (for lectures)	Dončov S. Nebojša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The acquisition of higher level theoretical and practical knowledge about the electromagnetic compatibility (EMC) problems and signal integrity and their solving on computer by using numerical techniques. Developing skills to conduct independent scientific-research work.		
Course outcomes	Ability to independently solve practical problems of electromagnetic compatibility and signal integrity by using numerical modeling techniques. Ability to design complex integrated circuits that meet EMC standards.		
Course outline			
Theoretical teaching	General EMC concepts and techniques. Sources of electromagnetic interference (EMI). EMI signal representation and characterization. The interference coupling mechanisms. Interference control techniques. Coupling of electromagnetic fields with multiconductor lines. Numerical simulation techniques (TLM, FDTD, FEM, MoM). Numerical simulation of the coupling between the integrated electronic systems. Principles of designing compact multifunctional integrated circuits (System in a Package - SiP and System on Chip - SoC). Multilayer printed circuit boards (PCBs) and multilayer printed wire boards (PWBs). Clock and power distribution.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Christos Christopoulos, Principles and Techniques of Electromagnetic Compatibility, Second Edition, CRC Press, 2007.		
2	V.Prasad Kodali, Engineering Electromagnetic Compatibility: Principles, Measurements, Technologies and Computer Models, Wiley-IEEE Press, 2001.		
3	Dipak L.Sengupta, Valdis V. Liepa, Applied Electromagnetics and Electromagnetic Compatibility, John Wiley & Sons, 2001.		
4	Matthew N.O. Sadiku, Numerical Techniques in Electromagnetics, CRC Press, 2001.		
5	Antonije Đorđević, Dragan Olćan, Testing of electromagnetic compatibility (in Serbian), Academic mind, Belgrade, 2012.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, numerical simulations on computer, consultations, seminar paper, laboratory work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Detection of Signals in Noise		
Lecturer (for lectures)	Perić H. Zoran, Milić N. Dejan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring knowledge in the fields of application of linear systems and decision making theories for signal detection from interference.		
Course outcomes	Detection of a known and an unknown signal in white and colored Gaussian noise. Maximization of signal-to-noise ratio and custom filters. Optimum filter for colored noise.		
Course outline			
Theoretical teaching	Linear systems. The noise factor. Optimal linear systems. Nonlinear Systems - direct method. Nonlinear systems - transformation method. Statistical signal detection. Optimal signal reception in the noise. Detection of a known and an unknown signal in white and colored Gaussian noise. Maximization of signal-to-noise ratio and custom filters.Optimum filter for colored noise. The A Posteriori Theory of Reception. Statistical theory of detection. Detection based on a single sample. Detection based on multiple samples. Estimation of signal parameters.		
Practical teaching (exercises, OFE, study and research	Lectures. Consultations. Study and research work.		
Textbooks/references			
1	D. Drajić, Uvod u statističku teoriju telekomunikacija, Akademska misao, Beograd, 2003.		
2	J. Proakis, M. Salehi, Digital Communications, McGraw-Hill Education, 5th edition, 2007.		
3	U.Spagnolini, Statistical Signal Processing in Engineering, Wiley, 2018.		
4	A. R. Webb, K. D. Copsey, Statistical Pattern Recognition, Wiley, 3rd Edition, 2011.		
5	V. N. Vapnik, Statistical Learning Theory (detection and estimation), Wiley-Interscience, 1998.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, Project work, Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Communication Algorithms and Applications		
Lecturer (for lectures)	Nikolić B. Zorica		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering the skills necessary to implement the major communication algorithms used in the detection and synchronization in both software and hardware implementation.		
Course outcomes	Mastering the implementation of adaptive algorithms in the software and hardware in order to provide some system functions.		
Course outline			
Theoretical teaching	The Wiener filter and linear prediction. Adaptive transversal filters. LMS, RLS allgorithms and their variations. Adaptive channel equalization. DFE equalization and its alternative confgurations. Synchronization. Algorithms for timing and carrier phase recovery. Algorithms for carrier frequency recovery. Synchronization in spread spectrum systems. Implementation of communication algorithms. The application of communication algorithms in DSP, FPGA and ASCI circuits.		
Practical teaching (exercises, OFE, study and research	Students work independently on the project (project presentation with discussion).		
Textbooks/references			
1	Nevio Benvenuto and Giovanni Cherubini: Algorithms for Communications Systems and their Applications, John Wiley & Sons Ltd, 2002.		
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Giving lectures. Students work independently on the project (project presentation with discussion).			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		5G and 6G Mobile Communications		
Lecturer (for lectures)		Milošević D. Nenad		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Introduction to the technologies that the future mobile communication networks will be based on, including software defined networks, network function virtualizaton and cognitive networks.			
Course outcomes	Undersatnding operating principles and analysis of cognitive communication networks, software defined networks, i.e. modern communication networks.			
Course outline				
Theoretical teaching	Modern mobile networks and development perspectives. General concept of the next generation networks. Adaptive network layer. Mobility management. Multi-hop cellular networks. Cognitive networks. Access point choice. Network optimization theory. Multi-operator spectrum sharing. Mobile networks and cloud computing.			
Practical teaching (exercises, OFE, study and research	Solving theoretical and practical problems in the form of seminar papers.			
Textbooks/references				
1	S. Glisic, Advanced wireless networks: technology and business models, Wiley, 2016			
2	G. Stüber, Principles of Mobile Communication, Springer International Publishing, 2017			
3	Y. Zaki, Future Mobile Communications: LTE Optimization and Mobile Network Virtualization, Vieweg+Teubner Verlag, 2013			
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching. Individual work with students. During study and research work.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Information Theory and Source Coding		
Lecturer (for lectures)	Perić H. Zoran, Jovanović Ž. Aleksandra		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Disseminating knowledge and getting acquainted with the latest achievements and research in the field of information theory and source coding.		
Course outcomes	The student will acquire knowledge that will enable him to follow professional literature and to engage in scientific research in the field of information theory and source coding.		
Course outline			
Theoretical teaching	Shannon entropy and differential entropy. Other measures for the amount of information and entropy. Markov's chain and hidden Markov models. Rate distortion heory. Source coding with fixed length of code words. Source coding with variable length of code words. Adaptive source coding based on robust quantizers. Coding algorithm based on lifting wavelet transform. Adaptive modulation and coding.		
Practical teaching (exercises, OFE, study and research	Project assignments.		
Textbooks/references			
1	T. M. Cover, J. A. Thomas, Elements of Information Theory, Wiley-Interscience, 2006.		
2	T. Berger, Rate-Distortion Theory, A Mathematical Basis for Data Compression, Englewood Cliffs, N.J.:Prentice-Hall, 1971		
3	J. Anderson, S. Mohan, Source and Channel Coding an Algorithmic Approach, Hingham, Massachusetts, U.S.A.: Kluwer Academic Pub.,1991.		
4	A. Gersho, R. M. Gray, Vector Quantization and Signal Compression, Kluwer Academic Publishers, 1992.		
5	D. Radunović, Wavelets, Springer, 2009.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations. Scientific research.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	10	**Written exam**	
Exercises		**Oral exam**	40
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Statistical Signal Processing		
Lecturer (for lectures)	Đorđević T. Goran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Improvement of the knowledge in the field of detection of signals transmitted over channels with intersymbol interference, iterative decoding and simulation of telecommunication systems.		
Course outcomes	The students will be able to conduct research activities in the field of optimal receivers for systems with intersymbol interference. They will have knowledge in the field of modeling and simulation of telecommunication systems in order to determine and improve their performance.		
Course outline			
Theoretical teaching	Stochastic signals. Systems for adaptive signal processing of stochastic signals. Adaptation algorithms. System identification. Prediction. Adaptive interference suppression. Optimal receivers for systems with intersymbol interference. Equalization methods: linear equalization, feedback equalization, iterative equalization. Adaptive linear equalization. Adaptive feedback equalization. Application of Viterbi algorithm to equalization. Iterative decoding. BCJR (Bahl-Cocke-Jelinek-Raviv) algorithm. Monte Carlo simulations and importance sampling method. Software implementations in MATLAB.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. B. Drajić, Introduction to Statistical Telecommunications Theory (in Serbian), Akademska misao, Beograd, 2003.		
2	M. C. Jeruchim, P. Balaban, K. Sam Shanmugan, Simulation of Communication Systems – Modeling, Methodology, and Techniques, Kluwer Academic/Plenum Publishers, NY, USA, 2000.		
3	S. Haykin, Adaptive Filter Theory, 4th edition, Prentice Hall, NJ, USA, 2002.		
4	S. Lin, D. J. Costello Jr., Error Control Coding, 2nd edition, Prentice Hall, NJ, USA, 2004.		
5	J. G. Proakis, M. Salehi, Digital Communications, 5th edition, McGraw-Hill, New York, USA, 2007.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures. Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	10	**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	40		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Communications Over Fading Channel		
Lecturer (for lectures)	Milović M. Daniela		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	The present course provides basics on digital communications over fading channel and diversity techniques for mitigation of fading effect.		
Course outcomes	Covered topics will train students to find and apply the solutions of engineering problems in digital communication over fading channel. Students will be able to analyze performances of modern wireless communication systems and to estimate its practical implementations.		
Course outline			
Theoretical teaching	Fading Channel Characterization and Modeling. Multipath fading. Log-normal shadowing. Frequency selective and nonselective fading. Flat fading channel modelling. Coherent detection Optimum receivers for fading channels. Diversity techniques for communication over fading channels (EGC, MRC, SC, GSC, T-GSC). MIMO systems. Optimum combining.		
Practical teaching (exercises, OFE, study and research	Auditory exercises introduce students to fundamental concepts of digital communications over fading channel.		
Textbooks/references			
1	Marvin K. Simon, Mohamed-Slim Alouini, Digital Communications over Fading Channels, Wiley Series in Telecommunications and Signal Processing, Second Edition, 2005.		
2	A. Papoulis, Probability, Random Variables and Stochastic Processes, McGraw Hill,1991		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, auditory exercises, homeworks, office hours.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Coherent Optical Telecommunication Systems		
Lecturer (for lectures)	Milić N. Dejan		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Students will be introduced to details about coherent systems in modern optical telecommunications and to the critical review of the methods used in analysis of such systems.□		
Course outcomes	Acquired knowledge enables understandig of the modern trends in optical communications, provides a background for estimating a practical usability of such trends, and introduces the students to academic research in the field of optical communications.		
Course outline			
Theoretical teaching	Coherent detection in optical communications. Differences between IM/DD and coherent systems. Modulation formats. Generation of RZ-DPSK signals. Homodyne and heterodyne detection. Balanced detection. Quadrature receivers. Synchronous and asynchronous demodulation. Interferometric detection. Phase noise. Phase and polarization diversity. Polarization modulation. Multiplexing of optical signals. TDM, FDM, WDM, SCM, CDMA. Polarization multiplexing. Cross-phase modulation. Spectral efficiency of IM/DD and coherent channels. Quantum capacity limits.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G. Agrawal, Lightwave Technology: Telecommunication Systems, John Wiley & Sons, 2005		
2	G. Jacobsen, Noise in Digital Optical Transmission Systems, The Artech House Library, London, 1994		
3	G. Agrawal, Fiber Optic Communications Systems, John Willey & Sons, 2002		
4	K. Iizuka, Elements of Photonics, Volume II, , John Wiley & Sons 2002		
5	A. Papoulis, Probability, Random Variables and Stochastic Processes, McGraw Hill, 1991		

Number of classes of active education per week during semester/trimester/year

Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Theory classes, consulatations, study and research work.			

Grade (maximum number of points 100)

Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Theory and Applications of Software Radio		
Lecturer (for lectures)	Milošević D. Nenad		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course	In this course, students gain knowledge of basic and modern concepts of software radio.		
Course outcomes	Students who successfully complete this course will be able to understand the products and software radio technology, to implement modern wireless systems, to have knowledge of the architecture of digital hardware and to understand the design methods.		
Course outline			
Theoretical teaching	The evolution of radio technology. Transmitter and receiver architecture. Antennas and RF front end. Multirate signal processing. Direct Digital Synthesis (DDS). Analog to digital and digital to analog conversion. Introduction to smart antennas and baseband signal processing. Antenna arrays and beamforming. Digital hardware choices. Software methods for software radio. Cognitive networking.		
Practical teaching (exercises, OFE, study and research	Students work independently on the project (project presentation with discussion).		
Textbooks/references			
1	J. Mitola III, Software Radio Architecture, John Wiley & Sons, 2000.		
2	T. Collins, R. Getz, Di Pu, A. Wyglinski, Software-Defined Radio for Engineers, Artech House Publishers, 2018.		
3	E. Grayver, Implementing Software Defined Radio, Springer-Verlag New York, 2013.		
4	Di Pu, A. Wyglinski, Digital Communication Systems Engineering with Software-Defined Radio, Artech House, 2013.		
5	J. H. Reed, Software Radio: A Modern Approach to Radio Engineering, Prentice Hall PTR, 2002.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Giving lectures. Students work independently on the project (project presentation with discussion).			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Advanced Modeling Techniques for RF Applications		
Lecturer (for lectures)		Marković V. Vera, Marinković D. Zlatica		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Acquiring the knowledge in the field of modern methods for modeling RF and microwave components, devices, subsystems and systems			
Course outcomes	Ability to use modern techniques for modeling in the field of RF frequencies. Ability to develop models of components, devices, or certain parameters / aspects of selected RF communication systems			
Course outline				
Theoretical teaching	Theoretical aspects of a modeling process as an integral part of the design process. Review of the most frequently used modeling techniques for RF applications. Introduction to the selected modeling techniques. Modeling components and devices for applications in RF and microwave communications. Modeling the propagation of mobile communication systems. Application of artificial neural networks for modeling RF and microwave communications. Model development in a selected field.			
Practical teaching (exercises, OFE, study and research	Independent research (literature review, analysis of specific problems and model development, writing and presentation of scientific work).			
Textbooks/references				
1	Scientific publications in a selected area			
2	Q. J. Zhang, K. C. Gupta, Neural Networks for RF and Microwave Design, Artech House, 2000.			
3				
4				
5				

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures; independent research work; consultations. (Note: publishing a scientific paper in a journal or a presentation at a conference replaces the oral part of the exam.)			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Free-space Optical Telecommunications		
Lecturer (for lectures)		Milić N. Dejan, Milović M. Daniela		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	Students will be introduced to details about free-space optical systems in modern optical telecommunications and to the critical review of the methods used in analysis of such systems.			
Course outcomes	Acquired knowledge enables understandig of the modern trends in free-space optical communications, provides a background for estimating a practical usability of such trends, and introduces the students to academic research in the field of optical wireless communications.			
Course outline				
Theoretical teaching	Basics of free-space optical telecommunication technologies. Integration of FSO in optical networks. Long range communications, satellite optical communications. Optical wireless technologies in closed spaces. Coherent and incoherent detection. Characteristics, modulation techniques and propagation efects. Optical components for FSO. Signal processing in optical an electrical domain. Diversity reception with different combining strategies.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	W. Heinz, Free Space Optics, Sams, 2001.			
2	S. Hranilović, Wireless Optical Communication Systems, New age publishers, 2006			
3	M. Katzman, Laser Satellite Communication, Prentice Hall, New York, 1991			
4	K. Iizuka, Elements of Photonics, Volume II, , John Wiley & Sons 2002			
5	A. Papoulis, Probability, Random Variables and Stochastic Processes, McGraw Hill, 1991			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Theory classes, consulatations, study and research work.			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**	**Points**	
Activity during lectures	5	**Written exam**	30	
Exercises	15	**Oral exam**	20	
Colloquia	30			
Projects				

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Signal and Data Processing		
Lecturer (for lectures)	Perić H. Zoran, Nikolić R. Jelena		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Providing knowledge about advanced signal and data processing. Training students to write scientific papers in this very current field of research.		
Course outcomes	Students will be able to understand, classify, analyze and process different signals and data and to design new or improved solutions to the problem of signal processing related to specific applications.		
Course outline			
Theoretical teaching	Estimation of signal parameters. Adaptive signal processing. Kalman and adaptive filtering. Compression of signals and data based on advanced techniques and algorithms. Compressive sensing. Introduction to statistical learning. Adaptive methods of statistical learning and data processing. Soft calculation methods. Classification and clustering techniques.		
Practical teaching (exercises, OFE, study and research	Lectures.Consultations. Project work.		
Textbooks/references			
1	G. James, D. Witten, T. Hastie, R. Tibshirani, An Introduction to Statistical Learning with Applications in R, Springer, 2017.		
2	Y. C. Eldar, G.Kutyniok, Compressed Sensing: Theory and Applications, Cambridge University Press, 2012.		
3	U.Spagnolini, Statistical Signal Processing in Engineering, Wiley, 2018.		
4	M.Vetterli,ˈJ. Kovacevic,ˈV. K. Goyal, Foundations of Signal Processing, Cambridge University Press, 2014.		
5	Lj. Stanković, Digital Signal Processing with Selected Topics: AdaptiveSystems Time Frequency Analysis Sparse Signal Processing, Create Space Independent Publishing Platform, 2015.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures, Power Point presentations, Consultations.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	5	**Written exam**	
Exercises	30	**Oral exam**	35
Colloquia			
Projects	30		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Systems Theory		
Lecturer (for lectures)	Antić S. Dragan, Mitić B. Darko		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering the control system theory content. Training the students for active literature monitoring and scientific research in the field of diferent control systems.		
Course outcomes	Ability of critical analysis of existing solutions and finding original solutions on selected topics in the control systems theory.		
Course outline			
Theoretical teaching	System definition, examples, history, importance and classification of control systems. The basic principles of control. Mathematical description of dynamical systems. A uniform approach to system analysis. Basic system performances. Technical requirements specification and principles of control system design. Performance evaluation. Some engineering problems. MATLAB implementations.□		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	G. C. Goodwin, S. F. Graebe , and M. E. Salgado, Control System Design, Prentice-Hall, 2000.		
2	R.C. Dorf, and R.H. Bishop, Modern Control Systems, Prentice-Hall, 2004.		
3	W. S. Levine, The Control Handbook, CRC Press, 1996.		
4	D. Šiljak, Stability of Control Systems, School of Electrical Engineering, University of Belgrade, Forum, 1974 (in Serbian)		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures / consultation (in accordance with the number of students); scientific research (review of the literature, concrete problem analysis and finding solution, writing and presentation of individual paper).			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	System Identification		
Lecturer (for lectures)	Nikolić S. Saša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Gain knowledge about modern system identification techniques, iterative identification methods and be familiar with a recent computer software tools for system identification.		
Course outcomes	Know how to use in practice modern computer systems and software tools for system identification as well as application of identification in adaptive control systems.		
Course outline			
Theoretical teaching	Plants classification. Identification algorithms and their convergence. Active identification. Gradient methods of identification. Single and multidimensional regression models. Nonlinear regression method. Iterative identification methods. Passive identification. Experiment planning. Forming of optimal identification algorithms. Theoretical background for Legendre, Laguerre, Chebyshev orthogonal polynomials. Design of almost and quasi orthogonal polynomials and their application in identification real dynamical systems. Application of orthogonal functions and filters in identification systems. Methods for assessing the quality of identification.		
Practical teaching (exercises, OFE, study and research	Introduction to MATLAB System Identification Toolbox and its application in identification of a real dynamic system. Elaboration of the presented methodical units through project assignments.		
Textbooks/references			
1	B. Danković, D. Antić, Z. Jovanović, Identification systems (in Serbian), Faculty of electronic Engineering, Niš, 2010,		
2	L. Ljung, “System identifikation”, Prentice Hill, New Jersey, 1997.		
3	P. Albertos, A. Sala, “Iterative Identification and Control”, Springer, 2002.		
4	MATLAB 2018, System Identification Toolbox,		
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Lectures or mentoring depending on the number of students. Students are encouraged to use scientific literature to deepen the knowledge from the lectures. Through research work and consultations with the professor, a student becomes able for writing a scientific paper on his own. A student is required to do a project assignment individually.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Robust Control		
Lecturer (for lectures)	Veselić R. Boban, Mitić B. Darko		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Introduction to the problems of model uncertainties and modeling errors, robust stability principles as well as control systems design methods for providing robust stability and robust performance.□		
Course outcomes	Provide the students with theoretical knowledge necessary for robust control systems design depending on present model uncertainties and given system specifications. Train the students to use computer support in analysis and synthesis of robust control systems.		
Course outline			
Theoretical teaching	Model uncertainties of linear dynamical systems and their representation in time and frequency domain. H2 and H∞ spaces and norms. Specifications of performances and limitations. Control plant model reduction. Model uncertainties and robustness. Robust stability and performance analysis. Linear fractional transformations. Structured singular value. Controller parameterization. Algebraic Riccati equation. H2 и H∞ control. Controller order reduction. H∞loop-shaping.□		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	K. Zhou, J. Doyle, Essentials of Robust Control, Prentice-Hall, 1998.		
2	S. Skogestad, I. Postlethwaite, Multivariable Feedback Control, John Wiley & Sons,1996.		
3			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures/consultations (depending on the number of students); study and research work (insight into literature, problem analysis, finding solutions, writing and presentations of individual paper)			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	0	**Written exam**	0
Exercises	0	**Oral exam**	50
Colloquia	0		
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Computer Controlled Systems		
Lecturer (for lectures)	Jovanović D. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring additional knowledge on methods of managing complex technological processes, centralized, distributed and hierarchical management. Study research work, preparation of professional-scientific work, as well as project development.		
Course outcomes	To gain knowledge about the application of computer systems in the design and realization of control systems in the process industry, management of distributed control systems and complex dislocated systems.		
Course outline			
Theoretical teaching	Problems of managing complex technological processes. Centralized management. Distributed management. Hierarchical management. Chosing real-time PCs. Input output devices. Real-time system software support. Merging computers with technological processes. Application of microcomputers in the design and implementation of control systems. Application of PLC and SCADA system in process management. Application of computers in the process industry, in the management of dislocated objects and in the management of utility systems.		
Practical teaching (exercises, OFE, study and research	Mastering method units of theoretical teaching through the preparation of seminars and projects.		
Textbooks/references			
1	G. Olsson, G. Piani, “Computer Systems for Automation and Control”, Prentice Hall, 1992.		
2	K. Erickson, J. Hedrick, “Plantwide Process Control”, John Wiley and Sons, 1999.		
3			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0

Teaching methods	Forms of teaching (classical - lectures or mentorship - consultations) according to the number of students. With the help of scientific journals and other literature, the student deepens the teaching material, and through consultations and study research work with the teacher, the student is trained for independent writing of scientific work. The student is obliged to do the project independently.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Robotics and Automation		
Lecturer (for lectures)	Raković M. Mirko, Nikolić N. Milutin		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Understanding the distinction, justification and needs for automated production. Introduction to the basic components of automation. Robot as a universal machine.		
Course outcomes	The building principles of automation system. Automation components and systems and their functional connections. Design and installation of automated manufacturing systems. Programmable Logic Controllers. The application of robots in automation of production.		
Course outline			
Theoretical teaching	Production system. Basic manufacturing strategy. Productivity and flexibility in production. Unregulated environment as a motive for robotics. Robots in manufacturing and non-manufacturing environments. The basic robot construction. Robot sensors. Final robot devices. Motion control and robot programming. Vision systems. Transport systems. Programmable Logic Controllers. Industrial interface. Flexible manufacturing cell design.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Lecture notes and slides (to be posted on the web page of the Faculty)		
2	B. Borovac, G.S. Đorđević, M. Rašić, Marko Raković, Industry robotics (in Serbian), FTN publiushing, Novi Sad, 2017.		
3	R.Shell, Handbook of Industrial Automation, CRC press, 2000, ISBN-13: 978-0824703738		
4	Thomas R. Kurfess, Robotics and Automation Handbook, CRC Press, 2004, ISBN: 0849318041		
5	Scientific and technical papers in accordance with student's needs		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Multimedia and interactive lectures. Demonstrations and auditory exercises.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	0	**Written exam**	0
Exercises	0	**Oral exam**	50
Colloquia	0		
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Inteligent Control		
Lecturer (for lectures)	Milojković T. Marko, Nikolić S. Saša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering advanced intelligent control techniques, designing intelligent control logic, optimizing the operation of intelligent systems, and designing and application of hybrid intelligent systems. Training for using internet platforms that are of interest for successful engagement in scientific research.		
Course outcomes	Mastering algorithms of intelligent systems for classification and optimization of databases, different types of learning of neural networks, practical realization of neural networks for different control tasks, principles of unsupervised learning and design of models of intelligent systems with unsupervised learning, methods for realization of Recommender systems, implementation of intelligent systems and their algorithms when working with Large Scale Machine Learning, the use of ANFIS in control logic of dynamical systems.		
Course outline			
Theoretical teaching	Intelligent systems for classification and database optimization. Types of neural network learning. Recommender systems. Large Scale Machine Learning. Hybrid Intelligent Systems. ANFIS.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	S. V. Kartalopoulos, Understanding Neural Networks and Fuzzy Logic: Basic Concepts and Applications, Wiley-IEEE Press, 1995		
2	M. Negnevitsky, “Artificial Inteligence”, Addison Wesley, 2002.		
3	H. Nguyen, N. Prasad, “A First Course in Fuzzy and Neural Control”, Chapman & Hall, 2003.		
4	L. Chambers, “The Practical Handbook of Genetic Algorithms”, Chapman & Hall, 2001.		
5			

Number of classes of active education per week during semester/trimester/year

Lectures	Exercises	OFE	Study and research work	Other classes
3	0	0	0	0

Teaching methods	Lectures/consultations (according to the number of students); study research work (insight into literature, problem analysis, finding solutions, writing and presentations of independent work).

Grade (maximum number of points 100)

Pre-exam duties	Points	Final exam	Points
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Advanced Mechatronics		
Lecturer (for lectures)	Perić Lj. Staniša		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring knowledge about basic theories and computer methodologies used in modelling and control of mechatronic systems.		
Course outcomes	Training students to independently design and control mechatronic systems.		
Course outline			
Theoretical teaching	Introduction: Mechatronic systems and review of linear systems. Minimal realizations of linear systems and Kalman decomposition. Function of matrices and phase portraits of linear systems. Phase portraits of nonlinear systems. Bifurcation theory. Lyapunov stability. Lie brackets and feedback linearization. Sliding mode control. Disturbance rejection. Systems with multiple inputs and multiple outputs. The principle of optimality. Linear Quadratic Regulation and Tracking. Introduction to digital control and z-domain. Digital control system design.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	Chi-Tsong Chen, "Linear system theory and design", Oxford University press, 1999.		
2	Hassan K. Khalil, "Nonlinear systems", Prentice Hall, 2002.		
3	Gene F. Franklin, J. David Powell, Abbas Emami-Naeini, "Feedback control of dynamic systems", Prentice-Hall, 2010.		
4	Clarence W. De Silva, "Mechatronics: An Integrated Approach", CRC Press, 2005.		
5	Sabri Cetinkunt, "Mechatronics", John Wiley & Sons Inc., 2007.		

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures/consultations (according to the number of students); study and research work (insight into literature, problem analysis, finding solutions, writing and presentations of independent work).			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Digital Control Techniques		
Lecturer (for lectures)	Veselić R. Boban		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Mastering the content that is related to the techniques of digital control. Training the students for active literature monitoring and scientific research in the field of digital control systems.□		
Course outcomes	Ability of critical analysis of existing solutions and finding original solutions on selected topics in the theory of digital control systems.□		
Course outline			
Theoretical teaching	Modern theory of digital control systems. Sampling in digital signal processing and digital control theory. Uniform approach to the analysis and synthesis of digital control systems. Some elements of analysis and synthesis of nonlinear digital control systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	R. H. Middleton, G.C. Goodwin, Digital Control and Estimation: A Unified Approach, Englewood Cliffs, N.J.: Prentice-Hall, 1990.		
2	A. Feuer and G. C. Goodwin, Sampling in Digital Signal Processing and Control, Boston: Birkhäuser, 1996.		
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures/consultations (depending on the number of students); study and research work (insight into literature, problem analysis, finding solutions, writing and presentations of individual paper)			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures	0	**Written exam**	0
Exercises	0	**Oral exam**	50
Colloquia	0		
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Optimal Control		
Lecturer (for lectures)	Antić S. Dragan, Veselić R. Boban		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	To obtain knowledge about modern methods in optimal control of industrial systems as well as optimal control in digital systems.		
Course outcomes	Ability to design optimal controllers and to apply them in industry and distributed systems. Forming of optimal control strategies and their implementation in control of complex and hierarchical systems.		
Course outline			
Theoretical teaching	Calculus of variations. Maximum principle. Normal and singular problem of optimal control. Structure and design of optimal controllers. Selected topics in dynamical systems optimization. Dynamic programming. Hamilton-Jacobi-Bellman differential equation. Optimal solution as a function of the state vector. Singular control in some linear systems with quadratic cost function. Optimal control in digital systems.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	D. Naidu, “Optimal Control Systems”, CRC Press, 2003.		
2	C. MacCluer, “Calculus of Variations”, Prentice Hall, 2005.		
3	F. L. Lewis, V. L. Syrmos: Optimal Control, John Wiley&Sons. Inc., New York, 1995.		
4			
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Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures / consultation (in accordance with the number of students); scientific research (review of the literature, practical problem analysis and finding solution, writing and presentation of individual paper).			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Variable Structure Systems		
Lecturer (for lectures)	Antić S. Dragan, Mitić B. Darko		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Gaining knowledge of the variable structure control systems with sliding mode and their application in the control of continuous- and discrete-time systems.		
Course outcomes	Knowledge of the methods for the implementation of variable structure control systems and their application in industrial processes.		
Course outline			
Theoretical teaching	The concept of variable structure systems and sliding mode. Continuous- and discrete-time sliding modes. Quasi sliding modes. Characteristics of systems with sliding mode control. Invariance conditions. Problems of mathematical description of sliding mode. Filippov's method. Equivalent control method. Stability of the systems with the sliding mode control. Systems with scalar and vector control. Methods for realization of sliding mode control in multivariable systems. Chattering reduction. Problems of realization of systems with sliding mode control. Sliding mode control in systems with finite zeros. Realization of sliding mode control based only on measuring of plant inputs and outputs. Examples of practical implementation of sliding mode control.		
Practical teaching (exercises, OFE, study and research			
Textbooks/references			
1	V.Utkin, J.Guldner, J.Shi, “Sliding Mode Control in Electromechanical System”, CRC Press, 1999.		
2	W. Perruquetti, J. P. Barbot, “Sliding mode control in engineering”, Marcel Dekker, 2002.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures/consultations (in accordance with the number of students); study research work (review of the literature, analysis of problems, finding solutions, writing and presentation of individual work).			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module	Common		
Type and level of studies	Doctoral studies		
The name of the course	Distributed Computer Control		
Lecturer (for lectures)	Jovanović D. Zoran		
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	10	**Course status (obligatory/elective)**	Elective
Prerequisites			
Course objectives	Acquiring knowledge about distributed control systems, communication networks and control algorithms for distributed systems.		
Course outcomes	Knowledge on practical applications of methods for managing distributed systems using modern computer technology, designing distributed control systems and their evaluation.		
Course outline			
Theoretical teaching	Configuration of distributed control systems. Communication networks. Control algorithms in distributed control systems. Economic justification of distributed management. Evaluation of distributed computer control systems. Microcomputer control networks. Trends in distributed computer management.		
Practical teaching (exercises, OFE, study and research	Mastering method units of theoretical teaching through the preparation of seminars, projects and scientific papers.		
Textbooks/references			
1	S. Tarbouriech, G. Garcia, A. Glattfelder, “Advanced Strategies in Control Systems with Input and Output Constraints”, Springer, 2007.		
2	G. Ellis, “Control Systems Design Guide”, Elsevier, 2004.		
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Forms of teaching (classical - lectures or mentorship - consultations) according to the number of students. With the help of scientific journals and other literature, the student deepens the teaching material, and through consultations and study research work with the teacher, the student is trained for independent writing of scientific work. The student is obliged to do the project independently.			

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program		Electrical Engineering and Computer Science		
Module		Common		
Type and level of studies		Doctoral studies		
The name of the course		Predictive Control		
Lecturer (for lectures)		Mitić B. Darko, Nikolić S. Saša		
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**	Elective	
Prerequisites				
Course objectives	The aim of the course is to provide a comprehensive knowledge of the theory of model predictive control (MPC).			
Course outcomes	Knowledge of MPC realization methods and their applications in industrial processes.			
Course outline				
Theoretical teaching	Robust model predictive control. Types of uncertainty. Feedback versus open-loop control. Nominal robustness. Robust MPC design of nonlinear systems. State estimation. Moving horizon estimation (MHE). Extended Kalman filtering. Particle filtering. Combined MHE/particle filtering. Output MPC. Linear constrained systems. Offset-free MPC. Nonlinear constrained systems. Distributed MPC (DMPC). Introduction and consideration of the existing results. Unconstrained two-player game. Constrained two-player game. Constrained M-player game. Nonlinear DMPC. Explicit control laws for constrained linear systems.□			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	Rawlings B. R., Mayne D.Q., Model Predicitive Control: Theory and Design, Nob Hill Publishing, 2009			
2				
3				
4				
5				
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Teaching methods depends on number of students (lectures or mentor). Students extend their lectures knowledge by reading scientific papers and other external literature. Students also get skils for writting scientific papers independently by consultations and research work. Students are obligatory to do project for the final exam.			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**	**Points**	
Activity during lectures		**Written exam**		
Exercises		**Oral exam**	50	
Colloquia				
Projects	50			

Specification for the book of courses

Study program			Electrical Engineering and Computer Science	
Module			Common	
Type and level of studies			Doctoral studies	
The name of the course			Adaptive Control Systems	
Lecturer (for lectures)			Perić Lj. Staniša, Milojković T. Marko	
Lecturer/associate (for exercises)				
Lecturer/associate (for OFE)				
Number of ECTS	10	**Course status (obligatory/elective)**		Elective
Prerequisites				
Course objectives	Familiarising students with different adaptive control methods for dynamical systems with uncertain parameters.			
Course outcomes	At the end of this course, students will have knowledge of adaptive control methods and will be trained to design their own control structures.			
Course outline				
Theoretical teaching	Parameter estimation in real time. On-line parameter estimation: gradient methods and least squares methods in continuous and discrete time. Parameter estimation with projection. Extremum seeking methods. Self-tuning regulators. Direct and indirect adaptive control: pole placement control (PPC), adaptive pole placement control (APPC), model reference control (MRC), model reference adaptive control (MRAC), adaptive backstepping with tuning functions. Machine learning methods: neuroadaptive control and reinforcement learning control. Practical aspects and implementation of adaptive control systems and introduction to computational learning theory.			
Practical teaching (exercises, OFE, study and research				
Textbooks/references				
1	Shankar Sastry, Marc Bodson, "Adaptive Control: Stability, Convergence and Robustness ", Prentice-Hall, 1994.			
2	Petros Ioannou, Jing Sun, "Robust adaptive control", Prentice Hall, 1996.			
3	Howard Kaufman, Itzhak Barkana, Kenneth Sobel, "Direct Adaptive Control Algorithms: Theory and Applications ", Springer, 1998.			
4	George Rovithakis, Manolis Christodoulou, "Adaptive Control with Recurrent High-order Neural Networks", Springer, 2000.			
5	Ioan Landau, Rogelio Lozano, Mohammed M'Saad, Alireza Karimi, "Adaptive Control: Algorithms, Analysis and Applications", Springer, 2011.			
Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
3	0	0	0	0
Teaching methods	Lectures/consultations (according to the number of students); study and research work (insight into literature, problem analysis, finding solutions, writing and presentations of independent work).			
Grade (maximum number of points 100)				
Pre-exam duties	**Points**	**Final exam**		**Points**
Activity during lectures		**Written exam**		
Exercises		**Oral exam**		50
Colloquia				
Projects	50			

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module			
Type and level of studies	Doctoral studies		
The name of the course	Scientific and Research Work 1		
Lecturer (for lectures)			
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	30	**Course status (obligatory/elective)**	Obligatory
Prerequisites			
Course objectives	Application of basic, theoretical methodological, scientific-professional and expert-applied knowledge and methods for solving concrete problems. The student studies the problem, its structure and complexity, and on the basis of conducted analyzes, concludes the possible ways of solving it. By studying literature, students are introduced to methods that are designed for solving similar tasks and engineering practice in their solving.		
Course outcomes	Training students to independently apply previously acquired knowledge from different areas they have studied to examine the structure of the given problem and its systemic analysis in order to draw conclusions about possible directions of its resolution. Practical application of acquired knowledge among students develops the ability to see the place and role of engineers in the selected area, the need for cooperation with other professions and teamwork.		
Course outline			
Theoretical teaching	Formed individually in accordance with the needs of the scientific or seminar work, its complexity and structure. Lecturer assigns the specific task to a student. Student studies professional and scientific papers dealing with similar topics, makes research in order to find solutions for the assigned task, or to carry out certain experiments in the laboratory. The work also includes computer simulations, statistical analyzes,and participation in writing research papers in the specific scientific field.		
Practical teaching (exercises, OFE, study and research	The experimental part of the work can be carried out in the laboratories at the Faculty.		
Textbooks/references			
1			
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
			11	

Teaching methods	The lecturer compiles the task and delivers it to the student. The student is obliged to prepare a seminar paper within the given topick using the proposed literature. During the course of the work, the lecturer can give additional instructions to the student, refer to certain literature, and further direct it in order to produce quality seminar work. Within the framework of scientific research, the student conducts consultations with the lecturer and, if necessary, with other lecturers dealing with issues related to the topic of work itself. Within the given topic, the student, if necessary, performs certain measurements, tests and other research or statistical processing of data.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module			
Type and level of studies	Doctoral studies		
The name of the course	Scientific and Research Work 2		
Lecturer (for lectures)			
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	30	**Course status (obligatory/elective)**	Obligatory
Prerequisites			
Course objectives	Application of basic, theoretical methodological, scientific-professional and expert-applied knowledge and methods for solving concrete problems. The student studies the problem, its structure and complexity, and on the basis of conducted analyzes, concludes the possible ways of solving it. By studying literature, students are introduced to methods that are designed for solving similar tasks and engineering practice in their solving.		
Course outcomes	Training students to independently apply previously acquired knowledge from different areas they have studied to examine the structure of the given problem and its systemic analysis in order to draw conclusions about possible directions of its resolution. Practical application of acquired knowledge among students develops the ability to see the place and role of engineers in the selected area, the need for cooperation with other professions and teamwork.		
Course outline			
Theoretical teaching	Formed individually in accordance with the needs of the scientific or seminar work, its complexity and structure. Lecturer assigns the specific task to a student. Student studies professional and scientific papers dealing with similar topics, makes research in order to find solutions for the assigned task, or to carry out certain experiments in the laboratory. The work also includes computer simulations, statistical analyzes,and participation in writing research papers in the specific scientific field.		
Practical teaching (exercises, OFE, study and research	The experimental part of the work can be carried out in the laboratories at the Faculty.		
Textbooks/references			
1			
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
			11	

Teaching methods	The lecturer compiles the task and delivers it to the student. The student is obliged to prepare a seminar paper within the given topick using the proposed literature. During the course of the work, the lecturer can give additional instructions to the student, refer to certain literature, and further direct it in order to produce quality seminar work. Within the framework of scientific research, the student conducts consultations with the lecturer and, if necessary, with other lecturers dealing with issues related to the topic of work itself. Within the given topic, the student, if necessary, performs certain measurements, tests and other research or statistical processing of data.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		

Specification for the book of courses

Study program	Electrical Engineering and Computer Science		
Module			
Type and level of studies	Doctoral studies		
The name of the course	Scientific and Research Work 3		
Lecturer (for lectures)			
Lecturer/associate (for exercises)			
Lecturer/associate (for OFE)			
Number of ECTS	30	**Course status (obligatory/elective)**	Obligatory
Prerequisites			
Course objectives	Application of basic, theoretical methodological, scientific-professional and expert-applied knowledge and methods for solving concrete problems. The student studies the problem, its structure and complexity, and on the basis of conducted analyzes, concludes the possible ways of solving it. By studying literature, students are introduced to methods that are designed for solving similar tasks and engineering practice in their solving.		
Course outcomes	Training students to independently apply previously acquired knowledge from different areas they have studied to examine the structure of the given problem and its systemic analysis in order to draw conclusions about possible directions of its resolution. Practical application of acquired knowledge among students develops the ability to see the place and role of engineers in the selected area, the need for cooperation with other professions and teamwork.		
Course outline			
Theoretical teaching	Formed individually in accordance with the needs of the scientific or seminar work, its complexity and structure. Lecturer assigns the specific task to a student. Student studies professional and scientific papers dealing with similar topics, makes research in order to find solutions for the assigned task, or to carry out certain experiments in the laboratory. The work also includes computer simulations, statistical analyzes,and participation in writing research papers in the specific scientific field.		
Practical teaching (exercises, OFE, study and research	The experimental part of the work can be carried out in the laboratories at the Faculty.		
Textbooks/references			
1			
2			
3			
4			
5			

Number of classes of active education per week during semester/trimester/year				
Lectures	**Exercises**	**OFE**	**Study and research work**	**Other classes**
			11	

Teaching methods	The lecturer compiles the task and delivers it to the student. The student is obliged to prepare a seminar paper within the given topick using the proposed literature. During the course of the work, the lecturer can give additional instructions to the student, refer to certain literature, and further direct it in order to produce quality seminar work. Within the framework of scientific research, the student conducts consultations with the lecturer and, if necessary, with other lecturers dealing with issues related to the topic of work itself. Within the given topic, the student, if necessary, performs certain measurements, tests and other research or statistical processing of data.

Grade (maximum number of points 100)			
Pre-exam duties	**Points**	**Final exam**	**Points**
Activity during lectures		**Written exam**	
Exercises		**Oral exam**	50
Colloquia			
Projects	50		