University of Niš
Faculty of Mechanical Engineering in Niš

COURSE DIRECTORY
DOCTORAL ACADEMIC STUDIES
MECHANICAL ENGINEERING

Niš, January 2020

COURSE DIRECTORY
DOCTORAL ACADEMIC STUDIES
Study programme MECHANICAL ENGINEERING

№	Code	Course title	S	Course status	Regular teaching classes		ECTS
					L	GIR	
FIRST YEAR							
1.	**D10001**	**Selected Topics in Advanced Mathematics**	**1**	**C**	**5**	**2**	**10**
2.	**D10002**	**Numerical Methods**	**1**	**C**	**5**	**2**	**10**
3.	**D10003**	**Methods and Organization of Scientific Research**	**1**	**C**	**5**	**3**	**10**
4.		***Course from Elective Block 1***	***2***	***E***	***4***	***3***	***10***
	D20101	*Selected Topics in Mechatronics*	*2*	*E*	*4*	*3*	*10*
	D20102	*Advanced Course in System Control*	*2*	*E*	*4*	*3*	*10*
	D20103	*Quantitative Logistics – Optimization, Decision-Making and Prediction*	*2*	*E*	*4*	*3*	*10*
	D20104	*Drive Systems in Transport Engineering*	*2*	*E*	*4*	*3*	*10*
	D20105	*Sustainable Transport Policy Modelling*	*2*	*E*	*4*	*3*	*10*
	D20106	*Selected Topics in Road Vehicles*	*2*	*E*	*4*	*3*	*10*
	D20107	*Ergonomics in Automotive Engineering*	*2*	*E*	*4*	*3*	*10*
	D20108	*Theory of Turbulent Flow*	*2*	*E*	*4*	*3*	*10*
	D20109	*Viscous Fluid Dynamics*	*2*	*E*	*4*	*3*	*10*
	D20110	*Selected Topics in Industrial Management*	*2*	*E*	*4*	*3*	*10*
	D20111	*Transport Processes in Thermal Engineering, Thermoenergetics and Process Engineering*	*2*	*E*	*4*	*3*	*10*
	D20112	*Analytical Mechanics*	*2*	*E*	*4*	*3*	*10*
	D20113	*Product Development*	*2*	*E*	*4*	*3*	*10*
	D20114	*Selected Topics in Mechanical Design*	*2*	*E*	*4*	*3*	*10*
	D20115	*Selected Topics in Production and Information Technologies*	*2*	*E*	*4*	*3*	*10*
	D20116	*Artificial Intelligence Methods and Tools*	*2*	*E*	*4*	*3*	*10*
	D20117	*Biomedical Products*	*2*	*E*	*4*	*3*	*10*
5.		***Course from Elective Block 2***	***2***	***E***	***4***	***3***	***10***
	D20201	*Adaptive Control Systems*	*2*	*E*	*4*	*3*	*10*
	D20202	*Machine Dynamics*	*2*	*E*	*4*	*3*	*10*
	D20203	*Information Systems in Mechatronics*	*2*	*E*	*4*	*3*	*10*
	D20204	*Flow Management in Transport Networks*	*2*	*E*	*4*	*3*	*10*
	D20205	*Structural Dynamics of Machines and Vehicles*	*2*	*E*	*4*	*3*	*10*
	D20206	*Advanced Course in Fluid Mechanics with Boundary Layer Theory*	*2*	*E*	*4*	*3*	*10*

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FIRST YEAR							
5.		***Course from Elective Block 2***	***2***	***E***	***4***	***3***	***10***
	D20207	*Theory of Turbomachinery*	*2*	*E*	*4*	*3*	*10*
	D20208	*Theory of Fluid Flow Transport*	*2*	*E*	*4*	*3*	*10*
	D20209	*Selected Topics in Innovation Management and Entrepreneurship*	*2*	*E*	*4*	*3*	*10*
	D20210	*Exergy Analysis Methods in Energy and Process Engineering*	*2*	*E*	*4*	*3*	*10*
	D20211	*Thermodynamics of Multiphase Flows*	*2*	*E*	*4*	*3*	*10*
	D20212	*Selected Topics in Mechanical and Hydromechanical Operations*	*2*	*E*	*4*	*3*	*10*
	D20213	*Selected Topics in Vibration Theory*	*2*	*E*	*4*	*3*	*10*
	D20214	*Theory of Composite Structures*	*2*	*E*	*4*	*3*	*10*
	D20215	*Theory of Elasticity and Fracture Mechanics*	*2*	*E*	*4*	*3*	*10*
	D20216	*Selected Topics in Joining Technologies*	*2*	*E*	*4*	*3*	*10*
	D20217	*Selected Topics in Railway Engineering*	*2*	*E*	*4*	*3*	*10*
	D20218	*Logic Synthesis of Digital Systems*	*2*	*E*	*4*	*3*	*10*
	D20219	*Integrated Tire Development*	*2*	*E*	*4*	*3*	*10*
	D20220	*Surface Engineering*	*2*	*E*	*4*	*3*	*10*
	D20221	*Architectures and Design of Information Systems*	*2*	*E*	*4*	*3*	*10*
	D20222	*Design of Biomedical Products*	*2*	*E*	*4*	*3*	*10*
6.		***Course from Elective Block 3***	***2***	***E***	***4***	***3***	***10***
	D20301	*Machine Vision*	*2*	*E*	*4*	*3*	*10*
	D20302	*Mechatronic Systems in Vehicles*	*2*	*E*	*4*	*3*	*10*
	D20303	*Optimal Systems in Mechatronics*	*2*	*E*	*4*	*3*	*10*
	D20304	*Intelligent Sensor and Actuator Systems*	*2*	*E*	*4*	*3*	*10*
	D20305	*Modelling and Simulation of Logistic Systems*	*2*	*E*	*4*	*3*	*10*
	D20306	*Nonlinear FEM Structural Analysis in Transport Engineering*	*2*	*E*	*4*	*3*	*10*
	D20307	*Simulation and Optimization of Internal Combustion Engine Operation*	*2*	*E*	*4*	*3*	*10*
	D20308	*Numerical Simulation of Fluid Flow*	*2*	*E*	*4*	*3*	*10*
	D20309	*Magnetohydrodynamics*	*2*	*E*	*4*	*3*	*10*
	D20310	*Unsteady and Unstable Turbomachinery Flow*	*2*	*E*	*4*	*3*	*10*
	D20311	*Theory of Non-Newtonian Fluid Flow*	*2*	*E*	*4*	*3*	*10*

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FIRST YEAR							
6.		***Course from Elective Block 3***	***2***	***E***	***4***	***3***	***10***
	D20312	*Selected Topics in Project Management*	*2*	*E*	*4*	*3*	*10*
	D20313	*Modelling in Thermal Engineering, Thermoenergetics and Process Engineering*	*2*	*E*	*4*	*3*	*10*
	D20314	*Numerical Simulation of Transport Processes in Thermal Engineering, Thermoenergetics and Process Engineering*	*2*	*E*	*4*	*3*	*10*
	D20315	*Optimization of Energy Systems and Processes*	*2*	*E*	*4*	*3*	*10*
	D20316	*Theory of Nonlinear Vibration*	*2*	*E*	*4*	*3*	*10*
	D20317	*Vibration and Stability of Elastic Bodies*	*2*	*E*	*4*	*3*	*10*
	D20318	*Tribology of Mechanical Systems*	*2*	*E*	*4*	*3*	*10*
	D20319	*Reliability of Mechanical Systems*	*2*	*E*	*4*	*3*	*10*
	D20320	*Advanced Flexible Manufacturing Systems*	*2*	*E*	*4*	*3*	*10*
	D20321	*Plasticity Technologies*	*2*	*E*	*4*	*3*	*10*
	D20322	*Advanced CAPP/CAM Systems*	*2*	*E*	*4*	*3*	*10*
	D20323	*Advanced FEM Analysis and Product Optimization*	*2*	*E*	*4*	*3*	*10*
	D20324	*Non-metallic Materials*	*2*	*E*	*4*	*3*	*10*
	D20325	*Knowledge-Based Engineering Systems*	*2*	*E*	*4*	*3*	*10*
	D20326	*Product Lifecycle Management Systems*	*2*	*E*	*4*	*3*	*10*
	D20327	*Engineering Analyses of Biomedical Products*	*2*	*E*	*4*	*3*	*10*

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SECOND YEAR							
7.		***Course from Elective Block L 1 (Measurement)***	***3***	***E***	***3***	***3***	***10***
	D3L101	*Computer Systems for Acquisition and Control*	*3*	*E*	*3*	*3*	*10*
	D3L102	*Wireless Sensor Networks*	*3*	*E*	*3*	*3*	*10*
	D3L103	*Measurement and Monitoring of Transport and Logistic Systems*	*3*	*E*	*3*	*3*	*10*
	D3L104	*Measurement and Experimental Research in Hydropower Engineering*	*3*	*E*	*3*	*3*	*10*
	D3L105	*Measurement in Thermal Engineering, Thermoenergetics and Process Engineering*	*3*	*E*	*3*	*3*	*10*
	D3L106	*Engineering Experiment and Application Software in Mechanics*	*3*	*E*	*3*	*3*	*10*
	D3L107	*Experimental Methods and Metrology*	*3*	*E*	*3*	*3*	*10*
	D3L108	*Measurement in Production Systems*	*3*	*E*	*3*	*3*	*10*
	D3L109	*Laboratory Materials Testing*	*3*	*E*	*3*	*3*	*10*
	D3L110	*Material Selection*	*3*	*E*	*3*	*3*	*10*
	D3L111	*Standards, Norms and Measurement in Biomedical Engineering*	*3*	*E*	*3*	*3*	*10*
8.		***Course from Elective Block 4***	***3***	***E***	***3***	***3***	***10***
	D30401	*Stochastic Systems*	*3*	*E*	*3*	*3*	*10*
	D30402	*Intelligent Control and Robot Systems*	*3*	*E*	*3*	*3*	*10*
	D30403	*Rehabilitation Robotics*	*3*	*E*	*3*	*3*	*10*
	D30404	*Optical System Design*	*3*	*E*	*3*	*3*	*10*
	D30405	*Micro- and Nanoelectromechanical Systems*	*3*	*E*	*3*	*3*	*10*
	D30406	*Cooperative Intelligent Transport Systems*	*3*	*E*	*3*	*3*	*10*
	D30407	*Dynamics of Mobile Machines*	*3*	*E*	*3*	*3*	*10*
	D30408	*Management in Transport*	*3*	*E*	*3*	*3*	*10*
	D30409	*Selected Topics in Internal Combustion Engines and Hybrid Systems*	*3*	*E*	*3*	*3*	*10*
	D30410	*Advanced Course in Automotive Engineering*	*3*	*E*	*3*	*3*	*10*
	D30411	*Fluid Biomechanics*	*3*	*E*	*3*	*3*	*10*
	D30412	*Theory of Flow Through Porous Media*	*3*	*E*	*3*	*3*	*10*
	D30413	*Numerical Simulation of Flow in Turbomachinery*	*3*	*E*	*3*	*3*	*10*
	D30414	*Model and Experimental Research into Hydraulic Machines and Fans*	*3*	*E*	*3*	*3*	*10*
	D30415	*Modern Management Concepts, Methods and Tools*	*3*	*E*	*3*	*3*	*10*

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SECOND YEAR							
8.		***Course from Elective Block 4***	***3***	***E***	***3***	***3***	***10***
	D30416	*Selected Topics in Central Heating, District Heating and Gas Engineering*	*3*	*E*	*3*	*3*	*10*
	D30417	*Selected Topics in Air Conditioning*	*3*	*E*	*3*	*3*	*10*
	D30418	*Selected Topics in Thermal Energy Plants*	*3*	*E*	*3*	*3*	*10*
	D30419	*Thermal Engineering Processes and Devices in Industry and Building Construction*	*3*	*E*	*3*	*3*	*10*
	D30420	*Selected Topics in Theory of Drying*	*3*	*E*	*3*	*3*	*10*
	D30421	*Selected Topics in Refrigeration Devices and Heat Pumps*	*3*	*E*	*3*	*3*	*10*
	D30422	*Selected Topics in Theory of Sustainable Development and Environmental Protection*	*3*	*E*	*3*	*3*	*10*
	D30423	*Heat and Mass Transfer in Fluidized Systems*	*3*	*E*	*3*	*3*	*10*
	D30424	*Stochastic Processes in Mechanical Systems*	*3*	*E*	*3*	*3*	*10*
	D30425	*Theory of Plates and Shells*	*3*	*E*	*3*	*3*	*10*
	D30426	*Dynamics of Nanostructures*	*3*	*E*	*3*	*3*	*10*
	D30427	*Simulation in Mechanical Design*	*3*	*E*	*3*	*3*	*10*
	D30428	*Selected Topics in Power Transmission*	*3*	*E*	*3*	*3*	*10*
	D30429	*Intelligent Manufacturing Systems and Technologies*	*3*	*E*	*3*	*3*	*10*
	D30430	*Process Modelling and Optimization*	*3*	*E*	*3*	*3*	*10*
	D30431	*Tire Behaviour Simulation*	*3*	*E*	*3*	*3*	*10*
	D30432	*Modelling, Implementation and Management of Engineering Processes*	*3*	*E*	*3*	*3*	*10*
	D30433	*Cyber-Physical Engineering Systems*	*3*	*E*	*3*	*3*	*10*
	D30434	*Manufacturing of Biomedical Products*	*3*	*E*	*3*	*3*	*10*
	D30435	*Thermal Comfort*	*3*	*E*	*3*	*3*	*10*
9.	**D3SIR1**	**GIR *directly in the function of the preparation of the doctoral dissertation***	**3**	***E***	**0**	**8**	**10**
10.	**D4SIR2**	**GIR *directly in the function of the preparation of the doctoral dissertation***	**4**	***E***	**0**	**20**	**30**
				Total	***6***	***34***	***60***

THIRD YEAR							
11.	**D5SIR3**	**GIR *directly in the function of the preparation of the doctoral dissertation***	**5**	***E***	**0**	**20**	**30**
12.	**D6SIR4**	**GIR *directly in the function of the preparation of the doctoral dissertation***	**6**	***E***	**0**	**20**	**30**
				Total	***0***	***40***	***60***

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN ADVANCED MATHEMATICS**
Professor/professors:	Predrag M. Rajković, Melanija S. Mitrović, Ljiljana M. Radović, Dragan S. Rakić
Course status:	Study programme core course*
ECTS credits:	10
Requirements:	None

Course objective

Expanding the knowledge in specific areas of mathematics (two out of the seven proposed areas are chosen) necessary for students' further scientific research.

Course outcome

Raising the general educational level, as well as further developing the systematic work of students. Solving real problems using scientific mathematical methods and procedures, mastering methods and techniques of research and application of knowledge in practice, with the aim of successfully following the doctoral curriculum and conducting scientific research.

Course content (two courses are chosen out of the proposed seven)

Theory classes

1. **Partial differential equations (Predrag M. Rajković)**
   Ordinary differential equations and systems. Total differentials. Definition and classification of partial differential equations (PDE). Formation and types of integrals. Geometric interpretation. First-order PDE. Homogeneous and inhomogeneous linear PDE. General total differential. Pfaff's equation. Lagrange-Charpit method. Classification of second-order PDE. PDE reducible to ordinary DE. Correct derivative. Cauchy's method of characteristics. Second-order PDE. Order reduction. Reduction to canonical form. PDE of hyperbolic, parabolic and elliptic type. D'Alembert's method of characteristics. Fourier method for separation of variables. Use of Laplace's transformation in PDE solving.
2. **Probability and Statistics (Melanija S. Mitrović)**
   Introduction. Sets – theoretical basis. Functions. Operations and algebraic structures. Basics of combinatorics. Euler's integrals. Probability elements. Algebra of events. Probability of events. Probability distribution. Random variable. Distribution function. Discrete and continues random variable. Elements of statistics. Population, random sample, statistics. Parameter estimation, confidence intervals. Testing of statistical hypothesis, parametric significance testing, certain nonparametric tests. Correlation and regression. Random processes. Markov's chains.
3. **Optimization methods (Predrag M. Rajković)**
   Problem formulation. Objective function and constraints. Linear optimization. Geometric and simplex methods. Transport problem. Nonlinear optimization. One-dimensional optimization. Multidimensional nonlinear optimization. Methods of coordinate and steepest descent. Newton method. Multicriteria optimization. Vector objective multicriteria function and constraints. Ideal solutions and marginal solutions. Pareto optimum. Global criteria method and method with weighted coefficients.
4. **Advanced course in linear algebra (Dragan S. Rakić)**
   Vector spaces. Linear independence. Base and dimension. Rank. Linear transformation and its matrix. Base change. Similarity. Four fundamental subspaces. Vector and matrix norms. Scalar product. Unitary spaces. Orthogonality. Least squares method. QR decomposition. Symmetrical, orthogonal, unitary, normal matrices. Projections and orthogonal projections. Eigenvalues and eigenvectors. Characteristic polynomial. Diagonalization. Spectral theorem. Positive definite matrices. Jordan canonical form. Decomposition of singular values.
5. **Calculus of variations (Dragan S. Rakić)**
   Introduction. Functionals and extremals. Necessary condition of extremum. Sufficient condition of extremum. Variational problems with moving boundaries. Functionals with higher derivatives. Functionals with several functions of the same variable. Functionals with functions of two variables. Certain classical variational problems. Rayleigh-Ritz approximation method. Isoperimetric problems.
6. **Graph theory (Ljiljana M. Radović)**
   Graph theory: graph definition, oriented and nonoriented graph, node degree, weight graphs, matrix representation of graphs. Paths in graphs, connectedness and distance. Trees, covering trees, Eulerian and Hamiltonian graphs. Graph search, depth and width search, determining the shortest path. Dijkstra's algorithm, Floyd-Warshall algorithm. Finding the smallest spanning tree, Prim's algorithm, components of connectedness. Advanced algorithms.
7. **Algebraic engineering (Melanija S. Mitrović)**
   Basic algebraic structures (semigroup, group, ring, field) and their application in engineering. Semigrids. Grids. Boolean algebra. Relational algebra. Formal languages. Automata. Process algebra.

Guided independent research

- Preparing students to do research within their doctoral dissertation.

Recommended literature

1. D. Milovančević, **Parcijalne diferencijalne jednačine [Partial differential equations]**, Mašinski fakultet u Nišu, Niš, 1996.
2. D. S. Mitrinović, **Uvod u specijalne funkcije [Introduction to special functions]**, Građevinska knjiga, Beograd 1975.
3. L. Andrews, R.L. Phillips, **Math. Techniques for Engineers and Scientists**, SCITech, 2003.

4. M. Stojaković, **Verovatnoća, statistika i slučajni procesi [Probability, statistics and random processes]**, Simbol, Novi Sad, 2007.
5. P. Stanimirović, N. Stojković, M. Petković, **Matematičko programiranje [Mathematical programming]**, Niš, 2007.
6. Carl D. Meyer, **Matrix Analysis and Applied Linear Algebra**, SIAM, 2000.
7. Stanimir Fempl, **Elementi varijacionog računa [Elements of the calculus of variations]**, Građevinska knjiga, 1965.
8. R. Lidl, G. Pilz, **Applied abstract algebra**, Springer, 1998.
9. L. Aceto, A. Ingolfsdottir, K. Gulstrand Larsen, J. Srba**, Reactive Systems: Modeling, Specification and Verification**, Cambridge University Press, 2007.
10. Д. Цветковић, С. Симић, **Дискретна математика, математика за компјутерске науке [Discrete mathematics, mathematics for computer science]**, друго измењено издање, Просвета, Ниш, 1996.

Number of active teaching classes	Lectures	5	Guided independent research	2

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The exam is taken by defending the independently written term papers (two term paper 50 points each).

* *Students choose two of the given areas.*

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**NUMERICAL METHODS**
Professor/professors:	Ljiljana D. Petković, Ljiljana M. Radović, Miloš M. Jovanović, Predrag M. Živković
Course status:	Study programme core course*
ECTS credits:	10
Requirements:	None

Course objective

Students are introduced to numerical methods for solving mathematical models that describe some physical phenomena in the field of mechanical engineering and optimization methods. Students first gain knowledge in the field of numerical analysis (which is compulsory) and then choose one of the areas related to the methods for solving differential equations, optimization methods or numerical methods in energy and process engineering.

Course outcome

Students are able to solve:

- practical scientific and technical problems in the field of mechanical engineering that are mathematically described by ordinary or partial differential equations,
- optimization problems.

Course content: (A-course is compulsory and one more course is chosen from group B)

Theory classes

A) Numerical analysis – compulsory part (Ljiljana D. Petković)

Systems of linear equations. Gauss method (with the choice of main element) and factorization methods. Iterative Jacobi and Gauss-Seidel procedures. Direct and iterative methods for matrix inversion. Matrix eigenvalues.

Solution of nonlinear equations. Iterative methods for simple and multiple zeros. Algebraic equations. Systems of nonlinear equations.

Polynomial function interpolation. Interpolation formulas with divided and final differences. Hermite interpolation. Trigonometric interpolation and fast Fourier transforms. Spline interpolation and B-splines. Bézier representation of curves and surfaces.

Theory of the best approximations. Least squares method. Mean-square approximation. Chebyshev mini-max approximation.

Numerical differentiation. Quadrature formulas. Newton-Cotes formulas. Romberg algorithm. Gauss quadrature.

B1) Numerical methods for ordinary and partial differential equations (Ljiljana D. Petković)

Numerical solution of ordinary differential equations. Multistep methods. Predictor-corrector methods. Difference equations. Convergence analysis. Systems of differential equations.

Contour problems. Guessing method. Finite difference method. Variation and projection methods. Sturm-Liouville problems. Variational formulation of contour problems. Ritz-Galerkin method. Finite element method. Model problem. Eigenvalue problems for differential equations.

Partial differential equations. Finite difference methods for solving elliptic equations. Explicit and implicit difference methods for parabolic equations. Finite difference method for hyperbolic equations. Variation and projection methods. Rayleigh–Ritz variational method. Galerkin method. Finite element method for elliptic equations.

B2) Optimization algorithms (Ljiljana M. Radović)

Linear optimization problems and algorithms. Nonlinear optimization problems and algorithms. Multicriteria optimization problems and algorithms. Vector objective function and constraints. Perfect and marginal solutions. Pareto optimum. Global criteria method. Method of weighted coefficients. Dynamic and global optimization algorithms. Genetic algorithms. Simulation-statistical methods. Monte-Carlo method and its applications.

B3) Special transformations and fractional calculus (Ljiljana D. Petković)

Functions defined by integrals (gamma, beta and error functions). Hypergeometric functions (HF). Bessel functions. Elliptic HF. Concepts of direct and inverse transforms. Laplace and Fourier transforms. Z-transform. Fractional integrodifferential calculus (integral, Riemann–Liouville and Caputo type derivatives). Fractional differential equations.

B4) Numerical methods in thermal engineering, thermoenergetics and process engineering (Predrag M. Živković)

Importance of heat transfer and fluid flow. Need to understand and predict. Differential equation of unsteady heat conduction in solid bodies. Conduction – numerical solution methods. Finite difference method. Finite volume method. Finite difference approximation for steady and unsteady heat conduction problems. Explicit method. Implicit method. Limitations from the aspect of the second principle of thermodynamics.

B5) Numerical methods in fluid mechanics (Miloš M. Jovanović)

Methods for describing and studying turbulent flows: statistical theories. Euler and Lagrange approach. Theory validation. Turbulent flows for large Reynolds numbers. Turbulence phenomenology: Kolmogorov approach, inertia, viscosity, influential factors. Dynamics: velocity derivatives, vortex stretching and entropy production. Stresses, stress production, turbulent dissipation – cause or effect of vortex stretching.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing term papers.

Recommended literature

1. Lj. Petković, **Numerička analiza [Numerical analysis]**, Prosveta, Niš 2003.
2. D. Braess, **Finite elements, University Press**, Cambridge 2001.

3. P. S. Stanimirović, N. V. Stojković, M. D. Petković, **Matematičko programiranje [Mathematical programming]**, Niš, 2007.
4. E. Polak, **Optimization – Algorithms and Consistent Approximations**, Springer, 1997.
5. Petrović Z., Stupar S., **Projektovanje računarom-metod konačnih razlika [Computer-aided design – finite difference method]**, Mašinski fakultet u Beogradu, 1992.
6. Versteeg, H. K., Malalasekera, W.: **An Introduction to Computational Fluid Dynamics: The Finite Volume Method**, Pearson Education Limited, 2007.

Number of active teaching classes	Lectures 5	Guided independent research 2

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Defence of independently written term papers (two papers 35 points each) and oral examination (30 points).

* **Numerical analysis** *is compulsory for all students. One extra area is chosen.*

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**METHODS AND ORGANIZATION OF SCIENTIFIC RESEARCH**
Professor/professors:	Vlastimir D. Nikolić
Course status:	Study programme core course
ECTS credits:	10
Requirements:	None

Course objective

Preparing students to do research within their doctoral dissertation.

Course outcome

Students' ability to publish scientific papers in international journals.

Course content:

Theory classes

- Manner of organization of scientific research – environment, information awareness, necessary resources, research plan – time frames and deadlines, research strategy – long-term goals and work packages, research background and introduction of novelty with application in one's own research. Innovative versus creative concepts.
- Use of modern means of information acquisition and analysis – libraries, the internet, exchange of information through direct contact.
- Research methods – analytical, experimental, synthetical – inductive versus deductive
    - Problem formulation, mathematical model and choice of method for solution
    - Laboratory and numerical experiments
    - Analysis of obtained results.
- Standard communication methods in international scientific public – text editors, programming languages, diagrams, result representation.
- Techniques of writing scientific reports and papers – organization, content, language, conclusions.
- Techniques of presentation of achieved results – accessories and programs, ways to prepare slides and oral communication.
- Open access science and presentation of results to the wider public (non-academic community, potential users, investors, etc.).
- Potential fund proposals (different ways of funding of scientific achievements).
- Analysis of the concept of scientific research and innovation projects – priority research areas, calls, writing project proposals, defining resources...
- Investigation of regulations and basic rules for project funding and assessment (Science Fund of the RS, Innovation Fund of the RS, EU funds).
- Preparation of competitive project proposals.

Guided independent research

- Preparing students to do research within their doctoral dissertation. Preparing students to work in project research teams.

Recommended literature

1. Зоран В. Поповић, **Како написати и објавити научно дело [How to write and publish a scientific paper]**, Академска мисао, Институт за физику, Београд, 2014.
2. Андреас Екснер, **Увод у објављивање научних публикација [Introduction to scientific publishing]**, (на српском), Кобсон, 2017.
3. Serbian Library Consortium for Coordinated Acquisition **-** www.kobson.nb.rs
4. Science Fund of the Republic of Serbia – fondzanauku.gov.rs
5. https://ec.europa.eu/programmes/horizon2020/en/h2020-sections-projects

Number of active teaching classes	Lectures	5	Guided independent research	3

Teaching methods

Theory classes, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 50 points. Multimedia presentation of work up to 50 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN MECHATRONICS**
Professor/professors:	Miloš S. Milošević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquisition of advanced knowledge of mechatronics as a multidisciplinary field of mechanical, electrical and control systems. Mastering the advanced principles of operation of mechanical and electrical components of mechatronic systems. Introduction to performed complex mechatronic systems. Mastering the advanced principles of control of complex mechatronic systems. Identification of possible directions of further development of mechatronics.

Course outcome

Training in identifying problems in complex multi-disciplinary systems, and then defining and solving tasks of design, modelling and control of mechatronic systems, as well as team work in the field of development of advanced mechatronic systems with special emphasis on the integration of basic modules of mechatronic systems (mechanical, electrical and control) in order to achieve optimal functioning of a system as a whole.

Course content

Theory classes

- Mechatronics as a multidisciplinary field of advanced mechanical, electrical and control systems
- Advanced principles of operation of mechanical systems
- Advanced principles of operation of electrical systems
- Advanced principles of operation of mechatronic systems
- The structure of complex mechatronic systems
- Advanced principles of control of complex mechatronic systems
- Advanced principles of prediction and estimation
- The further development of mechatronics

Practice classes

- Analysis of operation principles of advanced mechanical systems
- Analysis of operation principles of advanced electrical systems
- Analysis of complex operation principles of advanced mechatronic systems
- Identification of problems in complex multidisciplinary systems
- Analysis of control principles of complex mechatronic systems
- Design, modelling and control of complex mechatronic systems based on integration of basic modules of mechatronic systems (mechanical, electrical and control) in order to achieve optimal functionality of a system as a whole
- Examples of performed complex mechatronic systems

Recommended literature:

1. Bishop H. R., **The Mechatronics Handbook**, CRC Press, 2007.
2. Bishop H. R., **Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering**, Prentice Hall, 2004.
3. Karnopp D. C., Margolis D. L., Rosenberg R. C., **System Dynamics: Modeling, Simulation, and Control of Mechatronic Systems**, John Wiley & Sons, 2012.
4. Bolton W., **Mechatronics: A Multidisciplinary Approach**, Prentice Hall, 2009.
5. Isermann R., **Mechatronic Systems: Fundamentals**, Springer; 2003.
6. Miloš Petrović, **Elektromehaničko pretvaranje energije [Electromechanical transformation of energy]**, Naučna knjiga, 1988.
7. Đukan Vukić, **Elektrotehnika [Electrical engineering]**, Nauka, Beograd, 1997.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, tutorials, consultations, preparation of a project task

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADVANCED COURSE IN SYSTEM CONTROL**
Professor/professors:	Vlastimir D. Nikolić, Žarko M. Ćojbašić, Ivan T. Ćirić, Miloš B. Simonović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of analysing and designing control systems, development and application of advanced control techniques.

Course outcome

Students are able to analyse and design advanced control systems.

Course content

Theory classes

- Nonlinear control
- Advanced system stability analysis
- Methods of designing control and reconstructors in state space
- Design of digital control systems
- Optimal control
- Robust control
- Adaptive control
- Intelligent control

Guided independent research

- Training students to independently research written literature, scientific journals and web portals in the field of analysing and designing control systems.
- Development, design and implementation of advanced control systems.

Recommended literature:

1. B.N. Starkar, **Advanced Control Systems**, 1st edition, Phi Learning; 2013.
2. Roland S. Burns, **Advanced Control Engineering**, Elsevier, 2001
3. R. C. Dorf, R. H. Bishop, **Modern Control Systems**, 10th edition, Prentice Hall, 2004.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**QUANTITATIVE LOGISTICS – OPTIMIZATION, DECISION-MAKING AND PREDICTION**
Professor/professors:	Goran S. Petrović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring advanced knowledge, competence and computer skills in selected fields of quantitative logistics and applying them in solving complex logistic problems.

Course outcome

Students acquire knowledge and skills that enable them to conduct research independently, solve problems and plan complex logistic systems.

Course content

Theory classes

- Basics of modelling and optimization. Model development, mathematical model, optimization model.
- Mathematical modelling of logistic systems.
- Overview of various optimization methods and techniques in logistics – software implementation. Classical and global optimization methods. Artificial intelligence in optimization.
- Multicriteria optimization of transport and logistic systems. Complex location problems, vehicle routing problems, optimal distribution of resources.
- Multicriteria decision-making under uncertainty (probability methods – Markov decision processes, fuzzy decision-making, rough set theory).
- Business prediction problems (regression analysis, time series models).
- Application of the MATLAB software package in solving quantitative problems in logistics.

Guided independent research

- Training students to research written literature, scientific journals and web contents in the field of optimization, decision-making and prediction of logistic processes and systems. Laboratory and experimental research.

Recommended literature

1. Петровић Г., Милић П., Мадић М.: **Квантитативна логистика - вероватноћа, статистика и случајни процеси са применама [Quantitative logistics – probability, statistics and random processes with application]**, универзитетски уџбеник, Универзитет у Нишу Машински факултет у Нишу, 2018.
2. Петровић Г.: **Вишекритеријумска оптимизација процеса одржавања техничких система применом вероватносних метода и вештачке интелигенције [Multicriteria optimization of processes related to the maintenance of technical systems by applying probability methods and artificial intelligence]**, докторска дисертација, Машински факултет у Нишу, Универзитет у Нишу, 2013.
3. Боровић С., Николић И.: **Вишекритеријумска оптимизација – методе, примена у логистици и софтвер [Multicriteria optimization – methods, application in logistics and software]**, Центар војних школа ВЈ, Београд, 1996.
4. Мадић М., Недић Б., Радовановић М.: **Пословно и инжењерско одлучивање применом метода вишекритеријумске анализе [Business and engineering decision-making by applying multicriteria analysis methods]**, Универзитет у Крагујевцу, Факултет инжењерских наука, 2015.
5. Давидовић Б.: **Моделирање и одлучивање у логистичким процесима [Modelling and decision-making in logistic processes]**, АГМ књига д.о.о. Београд – Земун, 2016.
6. Xu Z.: **Uncertain Multi-Attribute Decision Making - Methods and Applications**, Springer-Verlag Berlin Heidelberg 2015.
7. Chattefuee, S., Hadi, A.S.: **Regression Analysis by Example,** Fourth Edition, John Wiley & Sons, 2006.
8. Montgomery, D.C., Jennings, C.L., Kulahci, M.: **Introduction to Time Series Analysis and Forecasting**, John Wiley & Sons. Inc,2008.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term paper.

Knowledge assessment (maximum number of points 100)

The exam is passed through an oral defence (30 points) of an independently written term paper (70 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**DRIVE SYSTEMS IN TRANSPORT ENGINEERING**
Professor/professors:	Vesna D. Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of analysis, modelling and development of mathematical models of drive systems in transport engineering – non-continuous external and internal transport machines (cranes, forklifts, elevators and cable cars).

Course outcome

Ability to study and analyse drive systems in transport engineering in the development, design and testing phases.

Course content

Theory classes

- Analysis of functions, structures and parameters of drive systems in non-continuous external and internal transport machines (cranes, forklifts, elevators and cable cars).
- Kinematics and dynamics of mechanical drive systems. Mechanical transmission in non-continuous transport machines. Mathematical models of mechanisms in non-continuous transport machines with a winch, rope and pulley, and electrical and hydrostatic drive (cranes, elevators and cable cars).
- Hydraulic (hydrodynamic and hydrostatic) transmission in non-continuous transport machines. Hydrodynamic transmission with classical, complex and differential converters. Hydrostatic transmission with hydraulic pumps and engines for the regulation of towing characteristics. Hybrid, hydrostatic-electrical transmission in non-continuous transport machines.
- Kinematic and dynamic analysis and optimal synthesis of manipulator lever mechanisms in non-continuous transport machines (forklifts, car lifts) with a hydrostatic drive.
- Analysis and synthesis of drive mechanisms in rotating platforms in non-continuous transport machines (car lifts, port and tower cranes). Development of dynamic mathematical drive models. Energy drive analysis using numerical simulation. Optimal selection of mechanism components with electrical and hydrostatic drives.
- Drive mechanisms and transmission in non-continuous external and internal transport machines with energy recuperation systems.
- Experimental testing of drive systems in non-continuous external and internal transport machines.

Guided independent research

- Solution of numerical tasks.

Recommended literature

1. Слободан Т., Давор О.: **Дизалице [Cranes]**, Машински факултет Београд, 2005,
2. Слободан Т.: **Транспортни уређаји - механизација транспорта [Transport devices – transport mechanization]**, Машински факултет, Институт за механизацију, Београд 1999.
3. Dresig H., Holzweißig F.: **Dynamics of Machinery Theory and Applications**, Springer, 2010.
4. Јаношевић Д., Јовановић В. : **Синтеза погонских механизама хидрауличких багера [Synthesis of drive mechanisms in hydraulic excavators]**, Машински факултет Универзитета у Нишу, Ниш, 2015.
5. Јаношевић Д.: **Пројектовање мобилних машина [Design of mobile machines]**, Машински факултет у Нишу, Ниш, 2018.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, consultations and independent research into drive systems in transport engineering.

Knowledge assessment (maximum number of points 100)

The exam is passed through an oral defence (30 points) of an independently written term paper (70 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SUSTAINABLE TRANSPORT POLICY MODELLING**
Professor/professors:	Nikola S. Petrović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge and skills for researching policy models, examining best practice examples and applying modern methods for assessing the performance and influence of transport policies and necessary sustainability.

Course outcome

Students acquire knowledge that enables them to define, systematize and analyse theoretical and methodological aspects of modelling policies and specificities of this process in the transport sector. Furthermore, students will be able to apply different methods and tools of transport policies.

Course content

Theory classes

- Sustainable development and resource management – the notion of ecological and sociological capital. Transport as part of the sustainable development strategy. Sustainable transport indicators and quantification methods.
- Modelling a sustainable transport policy. Models for the evaluation of transport system sustainability – statistic and dynamic approach. Transport policies in relation to potential and proposed transport development scenarios.
- Transport policy instruments in the function of sustainable development. Methods and tools in modelling policies (benchmarking, policy networks, development mapping, scenario method, etc.).
- Interdependence of types of transport, economic growth, urbanization and air pollution. Environmental Kuznets curve. Validity testing.
- Strategies and marketing of sustainable mobility. Procedures of assessing the performance and influence of policies and their implications on policy measures – analysis of best practice examples and public approval.

Guided independent research

- Training students to independently research written literature, scientific journals and web portals in the field of sustainable transport policies.

Recommended literature

1. Alabau A., Guijarro L.: **The electronic communications policy of the European Union**, Universidad Politécnica de Valencia, 2011.
2. Goodman J.W.: **Telecommunications policy-making in the European Union**, Edward Elgar, 2006.
3. Button K., Hensher D.: **Handbook of Transport Strategy, Policy and Institutions**, Elsevier, Netherlands, 2005.
4. Jean-Paul R., Comtois C., Slack B.: **The Geography of Transport Systems**, Third edition, Routledge, 2013.
5. Petrović N.: **Upravljanje uticajima urbanizacije i vidova saobraćaja na kvalitet životne sredine [Managing urbanization effects and types of traffic on environmental quality]**, doktorska disertacija, Univerzitet u Beogradu, Saobraćajni fakultet, Beograd, 2018.
6. Journals: Transportation Research Part A: Policy and Practice; Journal of policy modeling; Government Information Quarterly; Telecommunications policy; Ecological modelling; Journal of CO_2 Utilization.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN ROAD VEHICLES**
Professor/professors:	Boban D. Nikolić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge necessary for observing and understanding problems in the development of modern concepts of road vehicles and their vital systems.

Course outcome

Students acquire the necessary knowledge that enables them to conduct independent research and apply creative approaches in solving problems related to modern concepts of road vehicles and their systems.

Course content

Theory classes

- Systems of support elements in road vehicles. Structural requirements. Overview of already existing solutions; identification of adequate system or assembly elements and their positioning and dimensioning; analysis of basic loads to which structures are subjected.
- Modern concept of road vehicles with internal combustion engines, hybrid and electric drives. Specific requirements and solutions. Modular creation of concepts of road vehicles. Multifunctional vehicles.
- Modern passive and active safety systems in road vehicles. Requirements and limitations, possibilities for improvement and iterative creation of a safe environment and operation.
- Partially and fully autonomous road vehicles. Architecture of autonomous vehicles. Object detection, classification and positioning systems; choice of solutions, command and control activation, and system control in road vehicles.
- General knowledge of testing in the field of road vehicles. Vehicle performance testing. Vehicle safety testing. Testing of customized or completed vehicles. Vehicle testing by simulation in programming packages such as *CarSim*, *TruckSim*, etc.
- Braking systems in motor and towed vehicles. Characteristics, improvements and testing.

Guided independent research

- Training students to independently research written literature, scientific journals and web contents in the field of road vehicles, participation in the preparation and testing of road vehicles or a selected system.

Recommended literature

1. Stojić B., Poznanović N., Ružić D., Dorić J.: **Drumska vozila [Road vehicles]**, FTN Novi Sad, 2014.
2. Maurer M., Gerdes C., Lenz B., Winner H.: **Autonomous Driving - Technical, Legal and Social Aspects**, Springer, 2015.
3. Hillier, V.A.W.: **Hillier's Fundamentals of Motor Vehicle Technology**, 6th Edition, Book I, Oxford University Press, UK, 2014.
4. Cornel S.: **Alternative Propulsion for Automobiles**, Springer, 2017.
5. Stefanović A.: **Drumska vozila – osnovi konstrukcije [Road vehicles – basics of structures]**, MF Niš, 2010.
6. Todorović J.: **Ispitivanje motornih vozila [Motor vehicle testing],** JUMV, 1995.
7. Savaresi S., Taneli M.: **Active Braking Control Systems Design for Vehicles**, Springer, 2010.
8. Janković D., Todorović J., IvanovićG., Rakićević B: **Teorija kretanja motornih vozila [Theory of motor vehicle movement]**, MF Beograd, 2001.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper.

Knowledge assessment (maximum number of points 100)

Term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ERGONOMICS IN AUTOMOTIVE ENGINEERING**
Professor/professors:	Dragan A. Ružić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the theory of ergonomic principles in the construction of motor vehicles and technologies for the improvement of comfort and human working conditions.

Training students for an independent and science-based consideration of criteria and problems in ergonomic aspects of the motor vehicle environment, by applying theoretical, experimental and computer methods.

Course outcome

Students acquire multidisciplinary scientific knowledge of ergonomic aspects of motor vehicles and automotive engineering for the purpose of improving ergonomics and comfort.

Course content

Theory classes

- **Anthropometry**
  Dimension of the human body. Reference points. Anthropometric comfort conditions. Operating foot and hand controls.
- **Oscillations and vibrations in motor vehicles**
  Sources of oscillations and vibrations in motor vehicles. Evaluating the intensity of vibrations. The influence of oscillations and vibrations on humans. Comfort conditions. Reducing the oscillatory load on humans in vehicles.
- **Sound in motor vehicles**
  Basics of sound physics, the sense of hearing and sound perception. Adverse noise effect on humans. Acoustic comfort conditions. Methods of measuring noise in motor vehicles. Methods of reducing external and internal noise in motor vehicles.
- **Microclimate conditions**
  Thermal interaction between humans and motor vehicle cabs. Microclimate conditions in motor vehicle cabs. Influential factors for microclimate perception. Thermal feel and its evaluation: Operation temperature, Equivalent temperature, PMV and PPD indexes. Thermal comfort conditions in motor vehicles. Methods for analysing microclimate in motor vehicles. Equipment for the normalization of microclimate in motor vehicles.
- **Driver’s seat visibility**
  The sense of sight: light perception, field of vision, details recognition. Safety and comfort conditions: lighting conditions and geometric conditions. Equipment for improving visibility from the vehicle. Visual reception of information from vehicle instruments: information presentation, instruments and signals.

Guided independent research

- Preparing students to conduct research within their doctoral dissertation, by writing a term paper on the problems in ergonomics, in line with the proposed problem considered in the doctoral dissertation.

Recommended literature

1. Ружић Д.: **Моторна возила: ергономија [Motor vehicles: ergonomics]**, (уџбеник у припреми), Универзитет у Новом Саду, Факултет техничких наука, Нови Сад, 2020.
2. Ружић Д.: **Микроклима у моторним возилима [Microclimate in motor vehicles]**, монографија, Универзитет у Новом Саду, Факултет техничких наука, Нови Сад, 2016.
3. Grossman H.: **PKW Klimatisierung – Physikalischen Grundlagen und technische Umsetzung**, Springer, Heidelberg, 2013.
4. Bhise V.: **Ergonomics in the automotive design process**, Taylor & Francis Group, 2012.
5. Kroemer, K.: **Fitting the human**, Boca Raton: CRC Press, 2009.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper based on the choice and analysis of contemporary literature sources, application of experimental research and/or numerical procedures for problem modelling and analysis.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF TURBULENT FLOW**
Professor/professors:	Miloš M. Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introduce students to the course content related to turbulent flow physics.
- Train students to recognize, explain and define turbulent flow phenomena independently and based on scientific principles.
- Provide students with a basis for easy adoption of the course content that relies on the turbulent transfer of momentum, heat and mass.

Course outcome

- Acquired knowledge of fundamental theory of turbulent flow physics.
- Acquired skills in the methodology of phenomenological research of complex turbulent flows.
- Acquired basis for easy adoption of new course content that rely on turbulent transfer of momentum, heat and mass.

Course content

Theory classes

Introduction to turbulent flows

- Nature of turbulent flows. Research methods for turbulent flows. Turbulent diffusivity. Turbulent scales.

Turbulent transfer of momentum, heat and mass

- Reynolds equations. The turbulent transfer of scalars. Reynolds stresses. Turbulent scalar fluxes. Estimation of Reynolds stresses. Evaluation of turbulent scalar fluxes.

Statistical description of turbulence

- Statistical correlations. Fourier transformations and characteristic functions. Correlation functions and spectrum. The central limit theorem.

Characteristic scales of turbulence and similarity parameters

- Length of interference. Integral scale of turbulence. Turbulent micro-scales.

Dynamics of turbulent interactions

- Kinetic energy of the basic flow. Turbulent kinetic energy. The dynamics of vorticity. Fluctuations dynamics.

Dynamics of turbulent spectra

- One-dimensional and three-dimensional spectra. Local isotropy. Energy cascade. Turbulent energy spectra. Production and dissipation effects. Time spectra. Passive scalar spectra.

Guided independent research

- Preparation of students for working in adequate software on their doctoral dissertation by writing two term papers on the topics that are directly related to the problem defined in the doctoral dissertation.

Recommended literature

1. Žarko M. Stevanović, **Numerički aspekti prenošenja impulsa i toplote [Numerical aspects of momentum and heat transfer]**, Mašinski fakultet, Univerzitet u Nišu, ISBN 978-86-80578-81-3, (2008).
2. Miroslav Sijerčić, **Matematičko modeliranje kompleksnih turbulentnih transportnih procesa [Mathematical modelling of complex turbulent transport processes]**, Institut za nuklearne nauke - Vinča, ISBN 86-7877-005-8, (1998).
3. H. Tennekes and J. L. Lumley, **A First Course in Turbulence**, The Massachusetts Institute of Technology Press, Cambridge-Massachusetts-London, England, ISBN 0-262-20019-8, (1973).

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**VISCOUS FLUID DYNAMICS**
Professor/professors:	Živojin M. Stamenković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The main objective of this course is for students to acquire knowledge related to the phenomena present in fluid flow. They should acquire knowledge that will allow them to perform theoretical analysis of these problems, as well as to apply them practically in tasks related to energy engineering, process engineering, energy efficiency and ecology.

Course outcome

Students acquire necessary contemporary knowledge of the phenomena present in steady and unsteady viscous fluid flow and fluid flow in a boundary layer. Doctoral students are able to perform theoretical analysis of such tasks and apply it practically to problems.

Course content

Theory classes

Mathematical models of viscous fluid flow

- Basic equations
- General fluid flow properties
- Initial boundary problems

Correct solutions of viscous fluid flow equations

- Layered flow
- Flow with axial symmetry
- Nonlinear automodel solutions

Flow at small Reynolds numbers

- Stokes approximation
- Oseen's approximation
- Higher approximations

Boundary layer

- Boundary layer equations
- Automodel solutions of boundary layer equations
- Boundary layer with pressure gradient

Instability and turbulence

- Basics of hydrodynamic stability theory
- Turbulent flow

Numerical methods

- Initial and boundary problems for ordinary differential equations
- Development of viscous fluid flow
- Direct methods

Guided independent research

- Training students to independently research written literature, scientific journals and web portals in the field of laminar and turbulent fluid flow and fluid flow in a boundary layer.

Recommended literature

1. Саљников В., **Динамика вискозног нестишљивог флуида [Dynamics of viscous incompressible fluid]**, Машински факултет Београд, 1969.
2. Обровић Б, Петровић Р, **Механика флуида-виши курс [Fluid mechanics – advanced course]**, Универзитет у Крагујевцу, Машински факултет Краљево, Краљево 2008.
3. Radyadour Zeytounian, **Theory and Applications of Viscous Fluid Flows**, Springer-Verlag Berlin Heidelberg, 2004, ISBN: 978-3-642-07889-7

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN INDUSTRIAL MANAGEMENT**
Professor/professors:	Peđa M. Milosavljević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge and skills necessary for doctoral students in the field of industrial management and introduction to production and business processes in industry. Mastering the basic management functions. Students improve their level of competence and skills in the field of industrial management, develop their creative abilities to solve problems in industry, acquire specific skills for process management in industry, gain state-of-the-art knowledge in this field, and obtain the ability to improve industrial processes.

Course outcome

Students acquire knowledge and abilities in independent and team scientific and research work, which enables them to study and solve problems of contemporary corporate management. Students become capable of high-quality scientific research in industry and wider areas of industrial management, equipped with the competence that allows them to develop and apply managerial technologies, procedures and methods that enable a faster development of industry and society as a whole.

Course content

Theory classes

- Overview of current research in the fields of: human resource planning, organization and management, governance, business communication, work motivation, decision-making and control, business innovation, quality management, integrated management systems, strategic management, leadership and teamwork, process management and improvement, risk management, industrial process design, industrial system organization and management.

Guided independent research

- Training students to independently research written literature, scientific journals and web portals in the field of industrial management.

Recommended literature

1. Милосављевић П., **Инжењерски менаџмент [Engineering management]**, уџбеник, Машински факултет Универзитета у Нишу, 2015.
2. Ћосић И., Шешлија Д., Видицки П., **Основе индустријског инжењерства и менаџмента [Basics of industrial engineering and management]**, Факултет техничких наука, Нови Сад, 2015.
3. Глигоријевић Ж., Бошковић Г., **Индустријски менаџмент [Industrial management]**, ауторско издање, Ниш, 2013.
4. Стоиљковић В., Милосављевић П., и др., **Индустријски менаџмент [Industrial management]**, практикум, Машински факултет Универзитета у Нишу, 2010.
5. Сајферт З., **Менаџмент: теорија и пракса [Management: theory and practice]**, Универзитет у Новом Саду, Технички факултет "Михајло Пупин", Зрењанин, 2009.
6. Стоиљковић В. и др., **Интегрисани системи менаџмента [Integrated management systems],** CIM College и Машински факултет Ниш, 2006.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**TRANSPORT PROCESSES IN THERMAL ENGINEERING, THERMOENERGETICS AND PROCESS ENGINEERING**
Professor/professors:	Mića V. Vukić
Course status:	Study programme elective course*
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of heat and mass transfer, gas dynamics and combustion.

Course outcome

Students gain knowledge that enable them to independently study and solve problems related to conductive and convective heat transfer in laminar and turbulent fluid flow, as well as problems related to combustion theory and gas dynamics.

Course content

Theory classes

Heat and mass transfer

- A physical model of a system with transport processes. The concept of a continuum. Basic concepts, natural laws, definitions. Transport quantities. Basic laws for transport of quantities, momentum, heat, chemical potentials. The concept of control volume. The general form of the conservation transport equation for the control volume – Reynolds transport theorem. The differential form of the general law for the conservation of a field. Conservation laws in the integral (macroscopic) form. Reynolds decomposition. The generalization of conservation laws. Constitutive relations. Unambiguity conditions. Similarity theory in convective heat transfer. Approximations of conservation equations for convective heat transfer in laminar flow. Analytical solution of convective heat transfer in laminar flow. Heat transfer in turbulent flow. Molecular mass transfer. Convective mass transfer.

Gas dynamics

- Basic equations of compressible fluid flow. Basic properties of compressible fluid flow. Propagation of disturbances in compressible fluids. Quasi one-dimensional isentropic steady flow. Shock waves. Angled expansion waves. Quasi one-dimensional steady flow of compressible fluid with friction. Quasi one-dimensional steady diabatic flow of compressible fluid. Method of characteristics. Method of characteristics for unsteady quasi one-dimensional flow. Method of characteristics for two-dimensional steady supersonic flow.

Combustion process theory

- The general energy conservation equation for the combustion process. The four functional steps of the combustion process. Laminar flames. Premixed laminar flames. Turbulent combustion. Turbulent flames. Combustion models. Simple “mixed is burnt” models. Arrhenius’s combustion model. Integration of fundamental processes in combustion: diffusion, convection, reaction.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of heat and mass transfer, laminar and turbulent fluid flow, gas dynamics and combustion process theory.

Recommended literature

1. Stevanović Ž., **Numerički aspekti turbulentnog prenošenja impulsa i toplote [Numerical aspects of momentum and heat transfer]**, Grafika Galeb, Niš, 2008.
2. Илић Г., Вукић М., Радојковић Н., Живковић П., Стојановић И.: **Термодинамика II – основе простирања топлоте и материје [Thermodynamics II – basics of heat and mass transfer]**, МФ Универзитета у Нишу, Униграф Х-Copy, ИСБН 978-86-6055-056-1 Ниш, 2014.
3. Versteeg, H. K., Malalasekera, W. **An Introduction to Computational Fluid Dynamics: The Finite Volume Method**, Pearson Education Limited, 2007.
4. Robert D. Zucker, Oscar Biblarz, **Fundamentals of Gas Dynamics**, Wiley, ISBN 0471059676, 2002.
5. Tums S. R., **Introduction to Combustion – Concepts and Applications**, McGraw-Hill, NY, 1996.
6. Warnatz J., Maas U., Dibble R. W., **Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation / 4th Edition,** Springer, ISBN 3540259929, 2006.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

** Two of the above fields are selected*

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ANALYTICAL MECHANICS**
Professor/professors:	Goran B. Janevski
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	Passed exam in Selected Topics in Advanced Mathematics (D10001)

Course objective

Introducing students to differential and integral principles of theoretical mechanics.

Course outcome

Students acquire knowledge that enables them to independently study and solve problems in point dynamics, dynamics of particle systems, and body dynamics by using the basic differential and integral principles of mechanics.

Course content

- *Differential equations of motion of a system of particles*
  Free and non-free systems. Connections and their classification. Possible and virtual displacements. Ideal connections. General dynamic equation. Lagrange equations of the first kind. Principle of virtual displacements. D'Alembert's principle. Holonomic systems. Independent coordinates. Generalized force. Lagrange equations of the second kind and their testing. Theorem on the change in total energy. Potential, gyroscopic and dissipative forces. Appell's equations for non-holonomic systems. Pseudocoordinates. Equations of motion in a potential field. Lagrange's equations in the case of potential forces. Generalized potential. Unnatural systems. Hamilton's canonical equations. Ruth's equations. Cyclic coordinates. Poisson brackets.
- *Variational principle and integral invariants*
  Hamilton's principle and its second form. Fundamental (Poincaré-Cartan) integral invariant of mechanics. Generalized conservative systems. Whittaker equations. Jacobi equations. Maupertuis-Lagrange principle of least action. Move by inertia. Links with the geodesic paths in random motion of the conservative system. Poincaré universal integral invariant. Lee Hwa Chung theorem. Invariance of volume in phase space. Louisville's theorem.
- *Canonical transformations and Hamilton-Jacobi equations*
  Canonical transformations. Available canonical transformations. Hamilton-Jacobi equations. The method of separation of variables. Application of canonical transformations in disorder theory. The structure of an arbitrary canonical transformation. The criterion that a transformation is canonical. Lagrange brackets. Simplexity of Jacobi's matrix of canonical transformation.

Recommended literature

1. Gantmaher F. R., **Аналитичка механика [Analytical mechanics]**, Завод за издавање уџбеника, Београд, 1966.
2. АнђелићТ., Стојановић Р., **Рационална механика [Rational mechanics]**, Завод за издавање уџбеника СРС, Београд, 1966.
3. Meirovitch L., **Methods of Analytical Dynamics**, McGraw Hill, New York, 1970.
4. E.T. Whittaker**, Analytical dynamics of particles and rigid bodies**, Cambridge UP, 1970.
5. Симић С., **Аналитичка механика [Analytical mechanics]**, Факултет техничких наука Универзитета у Новом Саду, Нови Сад, 2006.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Theory classes, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**PRODUCT DEVELOPMENT**
Professor/professors:	Boban R. Anđelković, Aleksandar V. Miltenović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Mastering scientific methods used in the process of transforming knowledge to a technical system. Studying the methodology of the development of new products, trends and tendencies in technical systems.

Course outcome

Doctoral students acquire knowledge in researching new product methods and processes.

Course content

Theory classes

- Introduction to product development. Product development aspects.
- Methodology and tools in product development.
- Approaches to product development in the engineering and industrial environment.
- Methods in product development.
- Creativity and innovativeness in product development.
- Information systems and decision-making in product development.
- Calculations, simulations, experiments in product development (modelling, model creation, 3D scanning and printing, virtual reality, testing of structures and parts).
- Manufacturability of parts and assemblies.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of product development.

Recommended literature

1. Милтеновић В., Анишић З., Марјановић Н., Адамовић Д., Банић М., Милтеновић А.: **Развој производа [Product development]**, Машински факултет Ниш, 2015, s.660
2. Милтеновић В.: **Развој производа [Product development]**, Машински факултет Ниш, 2003. s.200.
3. Lindemann U.: **Methodische Entwicklung technischer Produkte**, Springer Verlag, Munchen, 2005.
4. Ehrlenspiel K., Lindemann U., Kiewert A.: **Kostengünstig Entwickeln und Konstruieren**. Berlin, Springer 1998.
5. Fronius S.: **Konstruktionslehre – Antriebselemente**, VEB Verlag Technik, Berlin, 1982.
6. Pahl G., Beitz W.: **Engineering Design – A Systematic Approach**, Springer-Verlag, 1991.
7. Огњановић, М: **Иновативни развој техничких система [Innovative development of technical systems]**, Машински факултет Београд 2014.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN MECHANICAL DESIGN**
Professor/professors:	Dragan S. Milčić, Jelena D. Stefanović-Marinović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring advanced knowledge with the aim of developing variant design solutions and choosing the optimal ones from the ergonomic, techno-economic and environmental-energy aspect. Basic technical indicators are the lifecycle in the area of low-cycle and high-cycle fatigue and reliability.

Course outcome

Students will be able to: follow the scientific and professional literature from the chosen field given in the course content; independently solve scientific research problems in the field at hand (by forming adequate analytical, numerical and experimental models); write scientific research papers independently or in a team; convey the acquired knowledge and skills to others.

Course content

Theory classes

Phases in the design process. Definition of performers of elementary, partial and general functions. Formation of variant solutions and their evaluation from the techno-economic aspect. Selection of the compromise solution. Variant designs. Product lifecycle. Unification and typification. Measurement chains. Provisions and regulations in the design process. Introduction to basic terms and regulations related to the design process in mechanical engineering. Necessity of complying with regulations. Compliance assessment. Harmonized standards. CE marking. Launching products into the market. Pressure vessels. Thick- and thin-walled vessels. Working stresses. Thermal strain. Critical stresses in static conditions. Selection of welded joints from the aspect of mutual position of welded parts. Types of angled and square butt joints (shapes and dimensions) and the domain of their application. Behaviour of structures in the area of low-cycle fatigue. Behaviour of structures in the area of high-cycle fatigue. Design of welded structures. Light structures. Manufacturability in the design process. Modelling and structural optimization of design shapes of machine elements and parts of mechanical systems. Application of optimization in the design process.

Guided independent research

Variant design solutions. Design of typified parts. Performers of elementary and partial functions. Formation and calculation of measurement chains. Application of standards in the design process. Calculation of vessels and other pressurized equipment. A design example with low-cycle fatigue. Dimensioning of performers of elementary functions. Determining the lifecycle. Calculation of welded structures. Calculation of light structures. Dimensioning of performers of elementary and partial functions. Design from the aspect of manufacturing and assembly. Application of CAD systems, simulation systems, visualization systems, RP technologies and PDM systems in the design process.

Recommended literature

1. Огњановић М.: **Конструисање машина [Machine design],** Машински факултет, Београд, 2011.
2. Wittel, Herbert, et al. Roloff/Matek Maschinenelemente : Normung, Berechnung, **Gestaltung - Lehrbuch und Tabellenbuch**. 20. überarb. u. erw. Aufl. 2011. Wiesbaden : Vieweg+Teubner Verlag, 2011.
3. Karl-Heinz Decker, Maschinenelemente **Funktion, Gestaltung und Berechnung,** Carl Hanser Verlag, München.
4. Милчић Драган: **Машински елементи [Machine elements]**, Машински Факултет Универзитета у Нишу, 2019.
5. Орлов П.: **Основи конструисања [Design basics]**, Машиностоение, Москва, 1980.
6. Јовичић, С., Марјановић, Н., **Основи конструисања [Design basics],** Факултет инжењерских наука, Крагујевац, 2011.
7. Стефановић-Мариновић Ј.: **Механички преносници - Планетарни преносници [Mechanical gearing – planetary gearing]**, Машински Факултет Универзитета у Нишу, 2017.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Laboratory exercises (25 points), computing tasks (15 points), term paper (30 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN PRODUCTION AND INFORMATION TECHNOLOGIES**
Professor/professors:	Miodrag T. Manić, Miroslav D. Trajanović, Miroslav R. Radovanović, Saša S. Ranđelović, Milan B. Trifunović, Jelena R. Milovanović, Predrag Lj. Janković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of production systems and technologies. Developing the ability for conceptual design and implementation of current and new production technologies. Understanding and conceiving technological processes.

Course outcome

Students acquire knowledge that enables them to independently research, analyse, model and apply certain production and information technologies in product development and product manufacturing technologies. Students should understand the interactions between software and hardware components of production technologies in a manufacturing environment.

Course content

Theory classes

- Highly productive cutting technologies
- Hybrid unconventional machining technologies
- CNC and DNC machining systems
- Intelligent technological systems
- Modern trends in unconventional machining procedures
- Disruptive production technologies
- Flexible production systems
- Selected topics in additive technologies
    - Overview and analysis of an expanded set of materials used in AT machines
    - Quality indicators in AT manufactured parts
    - Introduction to various software packages for the preparation of models of AT manufacturing
    - “Expert mode” in software for adjusting model geometry to AT machine manufacturing
    - Analysis of the application of different parameters and their influence on workpiece quality
    - Special AT application, AT trends, simultaneous 3D solidification, 4D printing

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of production and information technologies.

Recommended literature

1. Mikell P. Groover, **Automation, Production Systems, and Computer-integrated Manufacturing**, Prentice Hall, 2007
2. R. Bick Lesser, **Intelligent Manufacturing: Reviving U.S. Manufacturing Including Lessons Learned from Delphi Packard Electric and General Motors**, Productivity Press, 2013
3. Peter Smid, **CNC Programming Techniques: An Insider's Guide to Effective Methods and Applications**, Industrial Press Inc., 2016
4. Advanced **Modeling and Optimization of Manufacturing Processes**, Springer Series in Advanced Manufacturing, p. 380, Springer; 2011
5. Tetzlaff A.W., **Optimal Design of Flexible Manufacturing Systems**, Springer, 2013.
6. Srivatsan, T. S.,Sudarshan, T. S**, Additive manufacturing innovations, advances and applications**, CRC Press, 2016
7. Ian Wimpenny, Pulak M. Pandey, L. Jyothish Kumar (eds.) **- Advances in 3D Printing &Additive Manufacturing Technologies**, Springer Singapore, 2017
8. Maniruzzaman, M. (ed.), **3D and 4D Printing in Biomedical Applications -** Process Engineering and Additive Manufacturing-WILEY VCH, 2019

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ARTIFICAL INTELLIGENCE METHODS AND TOOLS**
Professor/professors:	Dragan T. Mišić, Mirko M. Stojiljković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Course objective is to introduce students to the basics of artificial intelligence and machine learning, and to train them to be able to use these tools in the field of mechanical engineering.

Course outcome

Students will be introduced to the modern techniques and tools used in the field of artificial intelligence and machine learning. At the end of the course, they will be able to recognize, select and use methods and tools that can help them in solving problems in the field of their interest.

Course content

Theory classes

- Functions and libraries of the Python programming language
- Heuristics
- Intelligent agents
- Problem solving by searching
- Genetic algorithms
- Uncertainty
- Fuzzy logic and control
- Monitored and unmonitored machine learning
- Bayesian decision theory
- Parametric and non-parametric methods of machine learning
- Decision trees
- Linear discriminative analysis
- Kernel machines
- Algorithm merging
- Reinforcement learning
- Neural networks and deep learning. Hyperparameter tuning
- Architectures for detection and segmentation of objects in an image (convolutional neural networks)
- Architectures for predicting time series (recurrent neural networks)

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of artifical intelligence and machine learning.

Recommended literature

1. Stuart J. Russell and Peter Norvig, **Artificial Intelligence**, A Modern Approach, 2016
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman**, The elements of statistical learning**, Data Mining, Inference, and Prediction,
3. Ian Goodfellow, Yoshua Bengio, Aaron Curville, **Deep Learning**, 2016
4. Selected scientific papers

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Classes are held in a consultative manner and through interactive cooperation with the advisor and the appointed supervisor. The supervisor introduces students to the course content directly. After being introduced to the course content, each student, in cooperation with the supervisor, chooses a topic for the project task and works on it. It is expected that the final result of the work on the project task is a manuscript, recommended for presentation at a scientific conference, regardless of its rank.

Knowledge assessment (maximum number of points 100)

Project task (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**BIOMEDICAL PRODUCTS**
Professor/professors:	Miroslav D. Trajanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Providing students with a sufficient level of knowledge of engineering products in the field of biomedicine that are used for diagnostic and therapeutic purposes, so as to enable them to conduct future research and development in the above field.

Course outcome

Students understand the principles of design, manufacturing and operation of engineering products used in the field of biomedical engineering for diagnostic and therapeutic purposes. Students are able to work in production organization that develop and manufacture biomedical products or in research institutions or companies that offer scientific and technological support to medical institutions.

Course content

Theory classes

- Diagnostic devices
- Smart diagnostic devices
- Diagnostic aids
- Programming solutions for diagnostics and early detection of disease symptoms
- Therapeutic devices
- Therapeutic aids
- Smart therapeutic aids
- Programming solutions for support of therapy processes
- Programming solutions for remote patient state monitoring
- Implants and their personalization

Guided independent research

- Project task – a concept solution of a new biomedical product with a defined purpose
- Preparation of a term paper that should be transformed into a scientific paper to be presented at a scientific conference or published in a journal

Recommended literature

1. (Eds.) Joseph D. Bronzino, Donald R. Peterson, **Medical Devices and Human Engineering** (2017) (Eds.), CRC Press, 1st Edition
2. Paul H. King, Richard C. Fries, Arthur T. Johnson, **Design of Biomedical Devices and Systems**, (2018), (Eds.) CRC Press, 4th Edition
3. **Biomedical Engineering and Design Handbook**, Volume 1 and 2, (2009), Myer Kutz (Editor), McGraw-Hill Education; 2nd Edition
4. **Medical Instrument Design and Development: From Requirements to Market Placements,** (2013), Claudio Becchetti, Alessandro Neri, Wiley
5. **Medical Instrumentation**: Application and Design (2009), John G. Webster (Editor), Wiley, 4th Edition
6. Selected scientific papers

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Classes are held in a consultative manner and through interactive cooperation with the advisor and, optionally, with the appointed supervisor – a researcher in the field of medicine or employed in the industry. The professor introduces students to the course content. After being introduced to the course content, each student, in cooperation with the advisor, professor and supervisor, chooses a topic for the project task and works on it. It is expected that the final result of the work on the project task is a manuscript, recommended for presentation at an international scientific conference or publication in a scientific journal.

Knowledge assessment (maximum number of points 100)

Project task (60) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADAPTIVE CONTROL SYSTEMS**
Professor/professors:	Miloš B. Simonović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to different methods of system identification and adaptive control for various classes of mechatronic objects.

Course outcome

The ability to design, implement and simulate adaptive controllers.

Course content

Theory classes

- Methods of system identification and adaptive control
- Online parameter estimation
- Selection of model order
- Indirect and direct adaptive control
- Controller synthesis. Adaptive PI and PID control
- Pole placement control (PPC), adaptive pole placement control (APPC), model reference control (MRC), model reference adaptive control (MRAC) for continuous and discrete systems
- System control with indeterminate and time variable parameters
- Stability of nonlinear systems, adaptive nonlinear control
- Robust adaptive control. Example of a PM synchronous motor
- Intelligent adaptive control
- Machine learning methods: neuroadaptive control and reinforcement learning control
- Application of adaptive control in mechatronic systems

Guided independent research

- Preparing students to independently research written literature, scientific journals and web contents in the field of adaptive control systems and system identification.

Recommended literature:

1. K. J. Åström, B. Wittenmark, **Adaptive Control**, Dover Publications; Second edition (December 18, 2008), ISBN-13: 978-0486462783 ISBN-10: 0486462781
2. I.D. Landau, R. Lozano, M. M'Saad, A. Karimi, **Adaptive Control –Algorithms, analysis and applications**, (2nd edition), Springer 2011, http://www.landau- **Systems**, Elsevier Ltd, 1999, ISBN 978-0-7506-3996-5 doi: https://doi.org/10.1016/B978adaptivecontrol.org/
3. G.Feng, R.Lozano, **Adaptive Control** -0-7506-3996-5.X5000-3
4. M. Szuster, Z. Hendzel, **Intelligent Optimal Adaptive Control for Mechatronic Systems**, Springer International Publishing, 2018, ISBN 978331968826 8 (online) ISBN 9783319688244 (print) doi:10.1007/978-3-319-68826-8
5. R. F. Stengel, **Optimal Control and Estimation**, Dover Publications, Inc. New York, 1994.
6. F. L. Lewis, D.Vrabie, V. L. Syrmos V. L. Szrmos, **Optimal Control**, John Willey & Sons, Inc., New York, 2012, ISBN-13: 978-0470633496, ISBN-10: 0470633492.
7. R. F. Stengel, **Optimal Control and Estimation**, Dover Publications, Inc. New York, 1994.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MACHINE DYNAMICS**
Professor/professors:	Nenad T. Pavlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring basic knowledge necessary for solving problems of machine dynamics.

Course outcome

The ability to analyse and solve problems of machine dynamics.

Course content

Theory classes

- Dynamic analysis of rigid machines (model formation, dynamic equation of motion, unsteady motion, processes in the periods of turning a machine on and off, flywheel dimensioning, synthesis of mechanisms for a given course of function).
- Dynamic analysis of machines with elastic links.
- Machine balancing: counterbalancing of rigid rotors, critical numbers of rotor revolutions, mass balancing of planar mechanisms.
- Vibration protection of machines: vibration activity of machines, rigid machine setup, vibration isolation.
- Torsional vibration in drive systems.
- Transversal vibration of rotating shafts.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals, and solve actual problems of machine dynamics.

Recommended literature:

1. Dresig H., Holzweißig,F., **Maschinendynamik**, Springer Verlag, 2006.
2. Burton P., **Kinematics and Dynamics of Planar Machinery**, Prentice-Hall, Inc., 1979.
3. Фролов К.В., **Теория механизмов и машин**, Высш. шк., Москва, 1987.
4. Harris C.M., Piersol A.G., **Harris' Shock and Vibration Handbook (**Section 30. Theory of Vibration Isolation**)**, Fifth Edition, McGraw-Hill, 2002. (www.knovel.com/knovel2/Toc.jsp?BookID=625).

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**INFORMATION SYSTEMS IN MECHATRONICS**
Professor/professors:	Ivan T. Ćirić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of information technology, developing and applying this technology in mechatronic systems.

Course outcome

Students are able to analyse and design complex information systems and implement them in mechatronic systems.

Course content

Theory classes

- Mechatronics, automation and control
- Information technology in Industry 4.0
- Computing methods and algorithms for modelling, simulation and optimization
- Software applications
- Data processing and data mining
- Data security
- Signal processing and filtering
- Information technology, WEB and computer networks
- Contemporary trends in information systems in mechatronics

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of information systems in mechatronics.
- Design and development of information systems.
- Implementation of complex information technology in mechatronic systems.

Recommended literature:

1. Vijayan Sugumaran, **Intelligent Information Technologies: Concepts, Methodologies, Tools and Applications**, IGI Global, 2007.
2. X.D. Xu, Bin Li, Q.M. Lu, X.Y. Yan and J.L. Li, **Mechatronics Engineering, Computing and Information Technology**, Trans Tech Publications, 2014.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**FLOW MANAGEMENT IN TRANSPORT NETWORKS**
Professor/professors:	Danijel S. Marković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The main objective of the course is to train students in applying heuristic and metaheuristics algorithms to solving problems in the field of means of transport routing and location problems.

Course outcome

Students acquire knowledge that enable them to independently study and solve routing problems of means of transport in networks for different conditions and in real time.

Course content

Theory classes

- Routing problems and determining the size and structure of a means of transport fleet. Routing problems of means of transport in the case of multiple bases.
- Heuristics and metaheuristic algorithms of static and dynamic distribution of means of transport in networks.
- Problems of determining the location of nods (hubs) in transport networks. Methods for solving location problems.
- Centres. *P*-centre problem. Methods for solving *p*-centre.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of the course.

Recommended literature

1. Теодоровић Д.: **Транспортне мреже [Transport networks]**, Универзитет у Београду, Саобраћајни факултет Београд, Београд 2007.
2. Ehmke, F.J.: **Integration of information and optimization models for routing in city logistics**, Spinger, 2012.
3. Yang, X. S.: **Engineering optimization: An introduction with metaheuristics applications,** John Wiley & Sons, 2010.
4. Gunther, Z., Roland, B., Michael, B.: **Metaheuristic search concept: A tutorial with applications to production and logistics**. Springer, 2009.
5. Bell, M., Iida, G.H.: **Transportation Network Analysis**. John Wiley & Sons, 1997.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Published scientific papers (2x35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**STRUCTURAL DYNAMICS OF MACHINES AND VEHICLES**
Professor/professors:	Predrag Đ. Milić, Dragan Z. Marinković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the need for dynamic analysis of transport and mobile machines and vehicles, as well as to basic numerical algorithms for calculating structural dynamics, determining structural parameters that influence dynamic behaviour, understanding the difference between numerical algorithms and properly choosing the right algorithm for the case of dynamic behaviour at hand, and reducing models for the purpose of an efficient dynamic analysis.

Course outcome

Students acquire knowledge that enable them to perform efficient dynamic analysis of transport and mobile machines and vehicles, as well as make changes in the design with the aim of affecting the dynamic behaviour of a structure, in the sense of improving it according to the predefined criteria.

Course content

Theory classes

- Fundamental equation of structural dynamics – understanding the dynamic response on the basis of a simple structure with one degree of freedom, damped and undamped vibration, harmonic excitation.
- Complex structures – spatial and temporal discretization. Structural FEM discretization, rigidity matrix, damping matrix, inertia matrix, loading vector. Discretization in the time domain – incremental approach.
- Modal analysis – importance, problem of eigenvalues, solution algorithms, eigenfrequencies and vibration modes, damping effect, examples from transport engineering.
- Structural damping – causes of energy dissipation, determination of structural damping, mathematical description.
- Direct integration of dynamic equation – explicit and implicit algorithms, their comparison, criteria for choosing algorithms to solve dynamic problems in transport engineering, examples.
- Modal superposition – model reduction by switching to modal space, factors od modal participations, criteria for choosing problem reduction modes, Craig-Bampton reduction, examples from transport engineering.
- MBS (multi-body system dynamics) approach to solving the dynamic behaviour of a large number of interconnected rigid bodies. Formalism of introducing the elastic behaviour of bodies.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of structural dynamics of machines and vehicles. Use of modern FEM and MBS software packages.

Recommended literature

1. Bathe K. J.: **Finite element procedures**, Pretince Hall, New Jersey, 1996.
2. Craig R. R., Kurdila J. A.: **Fundamentals of Structural Dynamics**, John Wiley & Sons. Inc., 2006, ISBN 13: 978-0-471-43044-5.
3. Јовановић М., Милић П.: **Примена методе коначних елемената у анализи структура: збирка решених задатака [Application of finite element method in structural analysis: a collection of solved tasks]**, Машински факултет Универзитета у Нишу, СВЕН, ISBN 978-86-6055-111-7 (COBISS.SR-ID 276159244), Ниш, 2019.
4. Gasch R., Knothe K., Liebich R.: **Strukturdynamik-Diskrete Systeme und Kontinua**, Springer-Verlag Berlin Heidelberg 2012, ISBN 978-3-540-88976-2.
5. Paz M., Kim H. Y.: **Structural Dynamics - Theory and Computation**, Springer Nature Switzerland AG 2019, ISBN 978-3-319-94742-6.
6. Borst R., Crisfield A. M., Remmers J.C. J., Verhoosel V. C.: **Non-linear finite element analysis of solids and structures**, ISBN 978-0-470-66644-9, John Wiley & Sons Ltd, 2012.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper.

Knowledge assessment (maximum number of points 100)

Independently written term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADVANCED COURSE IN FLUID MECHANICS WITH BOUNDARY LAYER THEORY**
Professor/professors:	Miloš M. Kocić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring necessary contemporary knowledge in the field of fluid flow phenomena. Providing doctoral students with the skills for theoretical and applied analysis of fluid flow problems.

Course outcome

Students acquire necessary contemporary knowledge related to the phenomena present in steady and unsteady, laminar, turbulent, and boundary layer fluid flow. Students acquire skills for theoretical analysis of such tasks, as well as for practical application to problems.

Course content

Theory classes

Steady flow of viscous incompressible fluids
- Solutions of Poiseuille, Couette and Poiseuille-Couette flows.
- Flow in ducts with non-cylindrical cross-sections.
- Two-dimensional flow, hydrodynamic stability of flow.

Unsteady flow of viscous incompressible fluids
- Plate started impulsively from rest in fluid. Body started from rest and moving with constant velocity in fluid.
- Fluid flow due to the oscillating plate. Flow development in a pipe.
- Wave movement. Plane waves. Progressive waves. Waves of finite amplitude. Wave energy. Wave drag.

Flow around the body and in variable cross-section ducts
- Fluid flow due to the motion of a circular cylinder.
- Fluid flow due to the motion of a sphere.
- Flow in convergent and divergent channels.
- Two-dimensional flow in a circular and rectangular cross-section bends.

Boundary layer theory
- Prandtl equations. Exact solutions of Prandtl equations for some classes of problems. Approximated parametric methods.
- Unsteady boundary layer. Two-dimensional spatial boundary layer.
- Three-dimensional boundary layer. Some problems of the theory of the three-dimensional boundary layer.
- MHD boundary layer. Temperature and diffusion boundary layer. Turbulent boundary layer.

Guided independent research
- Preparing students to independently research written literature, scientific journals and web portals in the field of laminar and turbulent fluid flow, and boundary layer fluid flow.

Recommended literature

1. Вороњец К., Обрадовић Н., **Механика флуида [Fluid mechanics]**, Грађевинска књига, Београд, 1970.
2. Саљников В., **Динамика вискозног нестишљивог флуида [Dynamics of viscous incompressible fluid]**, Машински факултет Београд, 1969.
3. Лојцјанскиј Л. Г., **Механика жидкости и газа**, Москва, 1978
4. Лојцјанскиј Л.Г., **Ламинарниј пограничниј слој**, Физмат гиз, Москва, 1962
5. Schlichting H., **Boundary layer theory**, McGraw Hill, 1979.
6. Batchelor G, **An introduction to fluid dynamics**, Cambridge University Press, 1984.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF TURBOMACHINERY**
Professor/professors:	Jasmina B. Bogdanović-Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge in the field of turbomachinery. Enabling students to formulate independently and based on scientific principles the equations of fluid motion through turbomachinery workspaces and to model turbomachinery working elements and determine their working characteristics.

Course outcome

Students gain knowledge in the theory of turbomachinery and acquire skills in modelling methodology and (analytical and numerical) solution of flow through cascades, as well as determination of turbomachinery characteristics.

Course content

Theory classes

- Equations of motion of liquids and gasses. Working processes in turbomachinery.
- Types of cascades in turbomachinery and their roles. Schematization of flow through cascades.
- Direct and indirect task of the theory of flow through cascades in turbomachinery.
- One-dimensional theory.
- Two-dimensional theory.
- Flow through straight planar cascade profiles.
- Flow through circular planar cascade profiles.
- Model of two interdependent two-dimensional flows.
- Flow averaging per circular component and flow calculation in a meridian plane.
- Flow calculation in axially symmetrical flow surfaces.
- Spatial flow in turbomachinery. Modelling of turbomachinery.
- Energy losses in turbomachinery.
- Unsteady phenomena in turbomachinery.
- Characteristics of axial, radial and diagonal turbomachinery.
- Turbomachinery design methods.
- Numerical solution of flow equations in turbomachinery by applying adequate software.

Guided independent research

Preparing students to independently research written literature, scientific journals and web portals in the field of design, testing and describing flow in turbomachinery.

Recommended literature

1. Бабић М., Стојковић С., **Основе турбомашина [Basics of turbomachinery]**, Научна књига, Београд, 1990.
2. Крсмановић Љ., Гајић А., **Турбомашине – теоријске основе [Turbomachinery – Theoretical basics]**, Машински факултет, Београд, 1992.
3. Gorla R.S.R, Khan A.A., **Turbomachinery – Design and Theory**, Marcel Dekker, Inc., 2003.
4. Turton R.K., **Principles of Turbomachinery**, Chapman & Hall, 1995.
5. Кирилов И. И., **Теорија турбомашин**, Лењинград, Мишиностроение, 1972.
6. Christopher E. Brennen, **Hydrodynamics of pumps**, Oxford University Press, 1994.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF FLUID FLOW TRANSPORT**
Professor/professors:	Saša M. Milanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of transport by fluid flow and enabling students to independently and on scientific principles formulate the equations of transport by fluid flow, model the fluid flow transport and determine the working characteristics of a system.

Course outcome

Students acquire skills and knowledge that enable them to independently study and solve problems in fluid flow transport.

Course content

Theory classes

- Pneumatic and hydraulic transport.
- Properties of transported materials.
- Basic parameters of fluid flow transport.
- Acting forces. Movement of solid material particles.
- Movement of non-homogeneous mixture of transported material and transport fluid.
- Pneumatic transport and elements of transport lines.
- Pneumatic transport of materials in straight pipelines and bends.
- Calculation of transport fluid (air) pressure drop in low pressure pneumatic lines for material transport and middle and high-pressure pneumatic lines for material transport.
- Dependence of pressure drop on air flow rate (critical velocity, minimum work).
- Hydraulic material transport. Hydraulic transport devices.
- Flow of suspensions. Transport of suspensions.
- Duran-Kondolio method, Goryunov method.
- Other methods and comparative analysis.
- Physical model of a system with transport processes. Concept of continuum. Primitive concepts, natural laws, definitions. Transport quantities. Constitutive relations.
- Fundamental laws of material transport, momentum, heat, chemical potentials.
- Concept of control volume. General form of conservation of a transport equation for control volume – Reynolds transport theorem. Differential form of the general law of field conservation. Conservation laws in the integral form. Reynolds decomposition.

Practice classes

- Computing tasks, in line with lectures, are performed for the purpose of completing one project task.

Recommended literature

1. Богдановић-Јовановић Ј., Милановић С., **Транспорт цевима - теоријске основе са примерима [Pipe transport – theoretical basis with examples]**, Универзитет у Нишу, Машински факултет у Нишу, 2019.
2. Богдановић Б., Милановић С., Богдановић-Јовановић Ј, **Летећи пнеуматички транспорт** [**Pneumatic transport of materials]**, Универзитет у Нишу, Машински факултет у Нишу, 2009.
3. Шашић М., **Прорачун транспорта флуида и чврстих материјала у цевима [Calculation of transport of fluid and solid materials in pipes]**, Научна књига, Београд, 1976.
4. Црнојевић Ц., **Транспорт чврстих материјала флуидима [Transport of solid materials by fluids]**, Машински факултет Београд, 2002.
5. Сијерчић М., **Математичко моделирање комлексних турбулентних транспортних прпцеса [Mathematical modelling of complex turbulent transport processes]**, Београд 1998.
6. Стевановић Ж., **Нумерички аспекти турбулентног преношења импулса и топлоте [Numerical aspects of turbulent momentum and heat transfer]**, Графика Галеб Ниш 2008.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN INNOVATION MANAGEMENT AND ENTREPRENEURSHIP**
Professor/professors:	Miloš D. Milovančević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course objective is to develop and improve the understanding of theoretical and empirical issues in the field of innovation and entrepreneurship. This course should enable students to clearly observe various changes, trends and influences in the field of innovation and entrepreneurship; to identify strategies and manners of change management in organizations (production/service); and to analyse the influence of changes brought on by innovation and entrepreneurship in existing companies (SME, companies – multinationals, large, industrial branches, institutions for innovation and entrepreneurship support, etc.). Furthermore, students should also understand the influence of a dynamic business environment on the creating of innovative corporate strategies and innovation management strategies.

Course outcome

Students who complete this course and pass the exam are able to independently and clearly gain an insight into the advanced understanding of research, methodology and approaches in the selected field; to compare and analyse principles within several theoretical traditional and modern approaches in the field of innovation and entrepreneurship; to show research capabilities in the critical examination of relations between theoretical explanations, methods, research problems and issues, and empirical data in the selected field; to apply the acquired knowledge and techniques to analyse certain research in the field.

Course content

Theory classes

- Nature of entrepreneurship and possibilities – introductory elements, business operations based on identifying possibilities in the surroundings, sources of possibilities; active research and discovery; link between possibilities and business concepts. Market elements of possibility commercialization – research techniques, assessment of the size of market possibilities. Business ideas and testing the viability of business ideas; incentives, creating business ideas in organizations. Discovering entrepreneurial possibilities and decision-making models. Concept of innovation – different research directions and assessment of application of certain models in variable external conditions. Business models – innovation processes, entrepreneurship, organization development. Analysis of research results in the field of innovation, entrepreneurship and technology. Identifying and choosing key research elements. Analysis of various techniques, tools and models for gaining a competitive advantage through innovation.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of innovation management and entrepreneurship.

Recommended literature

1. Милош Миловanчевић, **Иновациони менаџмент у е-пословању [Innovation management in e-commerce] -** Ниш, 2015, ИСБН 978-86-919717-0-0
2. Милош Миловaнчевић, **Иновациони менаџмент и заштита интелектуалне својине [Innovation management and intellectual property protection] -** Ниш, 2015, ИСБН 978-86-919717-1-7
3. Милош Миловaнчевић, Властимир Николић, Далибор Петковић, **Инжењерски менаџмент у условима савременог пословања [Engineering management in modern business conditions] -** Ниш, 2016, ИСБН 978-86-919717-2-4
4. Милош Миловaнчевић, **Предузетништво у инжењерском менаџменту [Entrepreneurship in engineering management] -** Ниш, 2017 ИСБН 978-86-919717-3-1
5. Милош Миловaнчевић**, Утицај глобализације на иновациони менаџмент [Influence of globalization on innovation management] -** Ниш, 2017, ИСБН 978-86-919717-5-5

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**EXERGY ANALYSIS METHODS IN ENERGY AND PROCESS ENGINEERING**
Professor/professors:	Goran D. Vučković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to:
- analyses based on the second law of thermodynamics;
- mechanisms of entropy generation and exergy destruction during heat transfer, fluid flow, flow mixing, chemical processes and other thermal flow processes;
- conventional and advanced exergy analysis;
- Exergoeconomics and exergoecology methods.

Course outcome

Students ability to analyse thermal flow processes with exergy tools.

Course content

Theory classes
- Analysis based on the second law of thermodynamics.
- The concept of entropy and negentropy.
- The entropy of the environment.
- Criteria of process spontaneity.
- Mass, energy and entropy balances for open thermodynamic systems.
- The concept of exergy.
- The concept and models of the environment in defining the exergy.
- Gouy-Stodola theorem.
- Exergy destruction of thermodynamic cycles and systems.
- Exergy losses.
- Mechanisms of entropy generation and exergy destruction during heat transfer, fluid flow, flow mixing and chemical processes.
- Analysis of thermal flow processes with exergy methods and tools.
- Conventional and advanced exergy analysis.
- Integration of processes by the error elimination method based on the second law of thermodynamics.
- Exergoeconomics and exergoecology.
- Costs of energy and exergy losses.
- Exergeconomic optimization procedure for energy systems.
- Methods of entropy generation minimization.

Guided independent research
- Preparing students to do research within their doctoral dissertation by writing a term paper with a task related to calculating mass, energy and entropy balances of a chosen thermodynamic system.

Recommended literature

1. Bejan A., Tsatsaronis G., Moran M., **Thermal Design and Optimization**, John Wiley and Sons, Inc., 1996.
2. Szargut J, Morris D, Steward F: **Exergy Analysis of Thermal, Chemical, and Metallurgical Processes**, Hemisphere Publishing Corporation, ISBN 0-89116-574-6, 1988.
3. Kotas T. J: **The Exergy Method of Thermal Plant Analysis**, Butterworths, London, ISBN 0-408-01350-8, 1985.
4. Wall G: **Exergetics**, Mölndal, Sweden, 2009.
5. Bejan A: **Entropy Generation through Heat and Fluid Flow**, John Wiley&Sons IP, ISBN 0-471-09438-2, 1982.
6. Moran M, Shapiro H: **Fundamentals of Engineering Thermodynamics**, 5th Edition, John Wiley&Sons IP, ISBN 13-978-0-470-03037-0, 2006.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, consultations, instructions for writing term papers.

Knowledge assessment (maximum number of points 100)
- Independent preparation of a term paper 70 points.
- Final exam – term paper defence and oral exam 30 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THERMODYNAMICS OF MULTIPHASE FLOWS**
Professor/professors:	Dragoljub S. Živković, Jelena N. Janevski
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to various thermodynamic phenomena occurring during different multiphase flows.

Enabling students to consider and solve various phenomena independently, based on scientific principles, define adequate physical and mathematical models and perform numerical simulations in the field of thermodynamics of multiphase flows.

Course outcome

Acquiring sufficient knowledge that students can use during scientific research in the field of thermodynamics of multiphase flows.

Course content

Theory classes

- Two-phase flows.
- Regimes of two-phase flows.
- Basic equations of two-phase flows.
- Pressure change in two-phase flows.
- Annular flow.
- Heat transfer in two-phase flows.
- Two-phase flows of the water vapour-water droplet type.
- Generation of the vapour phase in free and forced convection boiling.
- Generation of the vapour phase in non-equilibrium conditions.
- Crisis of heat transfer during boiling in large liquid volumes and in an evaporative channel.
- Heat transfer during condensation.
- Instability of two-phase flows.
- Two-phase flows in energy and process engineering.
- Safety of nuclear power plants.
- Safety of chemical plants.

Guided independent research

- Preparing of students to do research for their doctoral dissertation by writing a term paper.

Recommended literature

1. Bergles A.E., Collier J.G., Delhaye J.M., Hewitt G.F., Mayinger F., **Two-Phase Flow and Heat Transfer in the Power and Process Industries**, McGraw-Hill Book Company, Washington, New York, London, 1981.
2. IshiiM., **Two-fluid Model for Two-phase Flow**, 2.Int. Workshop on Two-Phase Flow Fundamentals, Rensselaer Polytechnic Institute, Troy, USA, 1987.
3. Wulff W., **Computational Methods for Multiphase Flow**, 2.Int. Workshop on Two-Phase Flow Fundamentals, Rensselaer Polytechnic Institute, Troy, USA, 1987.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (75 points) and oral exam (25 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN MECHANICAL AND HYDROMECHANICAL OPERATIONS**
Professor/professors:	Predrag M. Živković, Gordana M. Stefanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Broadening students' knowledge of the mechanical and hydromechanical operations in chemical and other industries and further studying the commonly used principles in mechanical and hydromechanical operations. Furthermore, students are introduced to theoretical principles of purification and practical techniques that can be used in gas, water or soil purification. Students are also given a broader insight into all the techniques and new trends in these areas.

Course outcome

After passing the exam students will be able to independently apply the calculation methodology of most commonly used mechanical and hydromechanical installations and their elements in the engineering practice, as well as calculate and dimension apparatus used to purify gases and liquids.

Course content

Theory classes

- Introduction, definition and classification of mechanical and hydromechanical operations.
- Modern grinding methods.
- Hydromechanical operations.
- Hydrokinetics of sedimentation.
- Fluid flow through porous media and filtration.
- Selected topics of centrifugation and centrifugal purifiers.
- Hydrodynamical classification.
- Separation of heterogeneous gaseous systems.
- Creation of heterogeneous liquid systems – Mixing.
- Wet gas dedusting procedures **-** General properties of aerosol systems and wet dust collector systems.
- Physical background of aerosol particles separation in wet dust collector systems.
- General air dedusting theory.
- Particle sedimentation.
- Energy theory of wet gas purification.
- Dry and wet gas purifiers.
- Centrifugal liquid purifiers-hydrocyclons.
- Liquid filtration, microfiltration, ultrafiltration, nanofiltration.
- Reverse osmosis and dialysis, electromembrane and electrochemical processes.
- New trends in mechanical and hydromechanical operations and purification techniques.

Guided independent research

- Preparing students for independent research within the scope of their doctoral dissertation, by writing a term paper whose subject is in direct correlation with the investigation of an adequate problem set in the research subject of the doctoral dissertation.

Recommended literature

1. Воређец Д.: **Технолошке операције [Technological operations]**, Научна књига, Београд, 1988.
2. Богнер М.: **Механичке операције [Mechanical operations]**, Научна књига, Београд, 1987.
3. Крстић М.: **Механичке операције и уређаји процесних постројења [Mechanical operations and devices in chemical plants]**, Универзитет у Сарајеву, Сарајево, 1970.
4. Богнер М., Вуковић Д.: **Проблеми из механичких и хидромеханичких операција [Problems in mechanical and hydromechanical operations]**, Универзитет у Београду, Београд, 1991.
5. D. Vuković, M.Bogner, **Tehnika prečišćavanja [Purification techniques]**, SMEITS, Beograd, 1996.
6. Nicholas G.Pizzi, **Water Treatment Operator Handbook**, American Water Works Association, 2005.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN VIBRATION THEORY**
Professor/professors:	Vladimir S. Stojanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to basics of vibration theory.

Course outcome

Acquiring knowledge in theoretical mechanics.

Course content:

Theory classes

- Free longitudinal vibration of prismatic bars. The differential equation of longitudinal vibrations. Solution in the form of trigonometric order. Forced longitudinal vibrations of prismatic bars. Vibrations of the bars with the load at the end. Free and forced vibrations.
- Torsional vibration of circular shafts. Free and forced vibrations.
- Free transverse vibrations of prismatic bars. Differential equations of transversal vibrations. The influence of the transverse force and rotatory inertia. Free vibrations of bars supported by a joint.
- Free vibrations of bars with different boundary conditions. Bars with free ends. Bars with fixed ends. Bars with one end free and the other fixed.
- Free vibrations of a beam resting on multiple supports.
- Forced vibrations of a simply supported beam with free ends.
- Forced vibrations of beams with different supports.
- The influence of axial force on transversal vibrations.
- Vibrations of beams on elastic foundation.
- Ritz method.
- Vibrations of variable cross-section bars.
- Beam vibrations due to bending and twisting.
- Membrane vibrations. Vibrations of rectangular membranes. Rayleigh-Ritz method.
- Vibrations of a plate. Vibrations of a rectangular plate. Vibrations of a circular plate. A circuit plate fixed along the contour. Other types of boundary conditions. The influence of tensile force in the middle surface of the plate.

Guided independent research

- Preparing students to do research within their doctoral dissertation.

Recommended literature

1. Vladimir Stojanović, Predrag Kozić, **Vibrations and stability of complex beam systems**, Springer International Publishing Switzerland, pp 166, ISBN 978-3-319-13766-7, 2015.
1. S. Graham Kelly, **Advanced vibration analysis,** by Taylor & Francis Group, LLC, 2007, Boca Raton, London, New York.
2. Данило Рашковић, **Теорија осцилација [Vibration theory],** Научна књига, 1965, Београд.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Theory classes, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF COMPOSITE STRUCTURES**
Professor/professors:	Ivan R. Pavlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to stresses and strains in composite plates.

Course outcome

Acquiring knowledge in the field of composite structures.

Course content

Introduction to composite materials.

- Fibre, laminate and granular composites. Mechanical behaviour of composite materials. Fundamentals of fibre reinforced composite laminate. Lamella. Laminate.

Macro mechanical behaviour of lamellas.

- Relations between stress and strain for anisotropic materials. Technical constants and their limitations. Isotropic and orthotropic materials. Relations between stress and strain in orthotropic materials. Relations between stress and strain for the clutch arbitrary fibre orientation. Mechanical testing of lamellas.

Macro mechanical behaviour of laminates.

- The classical theory of laminates. Stress and strain state of laminates. Changes in stress and strain. Forces and moments of arbitrary cross-section laminates. Special cases of laminates: single, symmetric, antisymmetric and asymmetric laminates. Interlaminar stresses.

Bending, buckling and vibration of composite plates.

- Differential equations of bending, buckling and vibrations. Limitations and assumptions. Differential equations of equilibrium of composite plates. Differential equations of buckling of composite plates. Differential equations of vibrations of composite plate. Bending, buckling and vibrations of specially orthotropic, symmetric angled, antisymmetric transverse and antisymmetric angled simply supported laminated plates.
- Mathematical modelling and simulation of composite structures using the MATLAB software package.

Recommended literature

1. Jones M. J., **Mechanics of composite materials**, McGraw-Hill Book Company, Washington, 1975.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF ELASTICITY AND FRACTURE MECHANICS**
Professor/professors:	Dragan B. Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Theory of elasticity is an upgrade of the knowledge acquired by students in the course on Strength of Materials at the undergraduate level. Students will become familiar with the theoretical foundations of fracture and damage mechanics. The objective of the course is to train students to do research in the theory of elasticity and fracture mechanics.

Course outcome

Acquiring knowledge and skills in theoretical and experimental research in the theory of elasticity and fracture mechanics of mechanical engineering systems and structures.

Course content

Theory classes

- Basic concepts of a solid body.
- Theory of stresses: Cauchy equation. Boundary conditions. Navier's equations of equilibrium.
- Theory of deformations: Cauchy deformation tensor. Saint-Venant's strain compatibility conditions.
- Relationships between stresses and strains: General Hooke's law. Elastic constants. Lame's equations. Beltrami-Michell's equations. Deformation work.
- Methods for solving problems of the theory of elasticity: Saint-Venant's problem. The principle of virtual displacements. Castigliano's theorem. Betti-Maxwell's theorem. Uniqueness solution of the problem of the theory of elasticity. Saint-Venant's principle.
- Plane problems of the theory of elasticity: Plane strains. Plane stresses. Application of polar coordinates. Solutions with polynomials. Application of trigonometric series. Application of complex variable function.
- Contact stresses. Elementary elasticity problems in space. Thermal stresses.
- Development of fracture and damage mechanics in the area of application in engineering. Physical models. Continuity and damage. The structure of materials, damage and fracture. The link between mechanical, electro-magnetic, thermal and chemical phenomena in the process of crack and formation propagation. Micro and macroscopic level of observation of cracks in the material.
- Basic relations of fracture mechanics. Models of the linear-elastic stress state in front of the crack tip. Solutions of basic equations of fracture mechanics by using the potential function. Kolosov-Mishelishvili relations. Westergaard's relationship. The general solution of fracture mechanics in plane models. Forms of crack propagation. Griffith's model of crack.
- Eshelby tensor of energy. Invariant integrals of fracture mechanics. Contour J-integral. Experimental determination of J-integral.
- Stress state and crack propagation in three-dimensional models.
- Cracks and fractures in elastic-plastic materials. Mises fracture criterion. Treska fracture criterion. Irwin's assessment of plastic flow field shape ahead of the crack tip. Plane stress state, i.e. the plane state of deformations in the plastic field. Dugdalle's and Barenblatt's model of crack. Plane stress state and transient behaviour of the material. R-curve. Elasto-plastic fracture and crack opening displacement (COD).
- Dynamic of crack propagation and arrest. Branching of cracks. Stability of cracks and crack propagation stability criteria.
- Crack growth due to fatigue. Speed of crack propagation in material fatigue.
- Local effects and interactions of cracks. Global and local stress state and strain energy. Methods to detect the presence of cracks in the material.
- Numerical methods and fracture and damage mechanics. Modelling of cracks and special finite elements.

Guided independent research

- Writing a term paper with original research results and preparing it for publication.

Recommended literature

1. Рашковић Д., **Теорија еластичности [Theory of elasticity]**, Научна књига, Београд, 1985.
2. Gdoutos E. E., **Fracture Mechanics**, Kluwer Academic Publ., Dordrecht, 1993.
3. Broek D., **Elementary engineering fracture mechanics**, Martinus Nijhoff Publishers, Dordrecht, 1986.
4. Hedrih (Stevanović) K., Jovanović B. D., **Mehanika loma i oštećenja [Fracture and damage mechanics]**, Mašinski fakultet, Niš, 2003.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN JOINING TECHNOLOGIES**
Professor/professors:	Miroslav M. Mijajlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring elementary and advanced knowledge in joining technologies (inseparable joints of parts).

Course outcome

Apart from the compulsory elementary knowledge of joining parts using technologies that do not allow for the separation of elements without their destruction, students who pass this exam will be able to choose, calculate, design and optimize complex links (joints). Students will be able to critically examine the advantages, disadvantages and possibilities of application of certain joining technologies.

Course content

Theory classes

- Introduction, basic joining technologies, division of joining technologies.
- Welding and soldering technologies for metallic and non-metallic parts.
- Bonding technologies for metallic and non-metallic parts.
- Combined joining technologies.
- Analysis, calculation of an appropriate joining technology.
- Quality. Standardization.
- Miscellaneous – in line with the needs and agreements with students, a field is chosen for students to study within the course.

Practice classes

- Computing exercises are completely adapted to lectures.

Recommended literature

1. Miroslav M. Mijajlović.: **Технологија заваривања 1 [Welding technology 1]**, Универзитет у Нишу, Машински факултет Ниш, 2017, с. 225, ISBN 978-86-6055-089-9
2. Miroslav M. Mijajlović: **Ауторизована предавања [Authorized lectures]** (скрипта, презентације, видео клипови, збирка важећих стандарда, материјали преузети са Интернета итд.), 2013-2019.
3. Јовановић, М., В.Лазић: **Практикум гасног (GPZ) и аргонског (TIG) заваривања [Gas (GPZ) and argon (TIG) welding practicum]**, Крагујевац, 2011.
4. Милорад Јовановић: **Практикум REL и MAG/MIG заваривања [REL and MAG/MIG welding practicum]**, Крагујевац, 2008.
5. Миомир Вукићевић et al: **Заваривање гасним поступком [Gas procedure welding]**, Краљево, 2007.
6. Robert Adams: Adhesive Bonding – Science, **Technology and Applications**, Woodhead Publishing, 2005.
7. EW. Thrall, RW Shannon: **Adhesive Bonding of Aluminum Alloys**, CRC Press, 2005.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, term papers, project tasks.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points and/or written exam) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN RAILWAY ENGINEERING**
Professor/professors:	Dušan S. Stamenković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the railway vehicle design process, with technical and exploitation characteristics as well as basic design parameters of tractive and hauled stock.

Introducing students to calculation procedures for certain railway vehicle assemblies and with type and serial testing of railway vehicles.

Introducing students to modular concept design of modern railway vehicles and their maintenance.

Introducing students to stationery and on-board diagnostic systems on railways.

Course outcome

Application of acquired knowledge in the field of railway vehicle design during modelling and calculation of specific mechanical assemblies of railway vehicles. Enabling students to independently define/improve a railway vehicle maintenance plan and programme based on the usage of modern diagnostic systems.

Course content

Theory classes

- Modular design. Phases in the railway vehicle design process.
- Locomotives. Motor trains. High-speed trains. Maglev trains. Passenger cars. Freight cars. Basic technical and operational characteristics. Characteristics of railway vehicles.
- Main assemblies of railway vehicles. Propulsion system. Running gear. Bogie. Wheel set. Braking system. Suspension system. Underframe. Car body. Frame. Buffing and draw gear. Equipment of railway vehicles.
- Propulsion systems. Diesel-hydraulic, diesel-electric and electric propulsion systems. Starting and stopping. Wheel traction force.
- Modelling of railway vehicles. Modelling of running gear. Modelling of wheel set. Underframe modelling. Modelling of buffing and draw gear.
- Testing of railway vehicles. Type and serial testing. Testing of assemblies and devices of railway vehicles. Standards and regulations.
- History of maintenance. Modern maintenance concepts.
- Continuous monitoring of railway vehicles. Preventive periodic inspections and repairs. Regular repairs. Modifications and reconstruction of railway vehicles.
- Stationary diagnostic systems. Diagnostic systems on the train – on-board systems.
- Information systems in operation and maintenance of railway vehicles.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of modern railway vehicles.

Recommended literature

1. Радосављевић А., Кожул Т., Бечејац Љ, **Техничко-експлоатационе карактеристике вучних возила на ЈЖ Београд [Technical and exploitation characteristics of tractive stock on a YR Belgrade**]**,** 1998.
2. Пајић Д., **Вучна возила [Tractive stock]**, Машински део, Београд 1981.
3. Стаменковић Д, **Одржавање железничких возила [Maintenance of Railway Vehicles]**, Машински факултет Ниш, 2011.
4. Gerhard B.: **Maintenance of ICE Train Sets -** Railway Technical Review, N3 1996.
5. Lagnebäck R.: **Evaluation of wayside condition monitoring technologies for condition-based maintenance of railway vehicles**, Luleå University of Technology-Sweden, 2007.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, term test and term paper.

Knowledge assessment (maximum number of points 100)

Term test (35 points), term paper (35 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**LOGIC SYNTHESIS OF DIGITAL SYSTEMS**
Professor/professors:	Vladislav A. Blagojević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of synthesis of digital systems.

Course outcome

Students acquire knowledge that enable them to independently study and solve problems in the design of digital systems.

Course content

Theory classes

- Introductory considerations.
- Elements of discrete mathematics.
- Switching functions.
- Minimization of switching functions.
- Functions and structures of switching networks.
- Combining switching networks.
- Logic synthesis of combining digital systems.
- Sequential switching networks.
- Logic synthesis of sequential digital systems.
- Components of digital systems.
- Technical implementation of digital systems.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of digital systems.

Recommended literature

1. Стојиљковић М., **Логичка синтеза пнеуматских система [Logic synthesis of pneumatic systems]**, Машински факултет Ниш, Ниш, 2009.
2. Godse A.P., Godse D.A., **Digital System Design**, Technical Publication Pune, Pune, 2008.
3. Ferdjallah M., **Introduction to Digital Systems**, John Wiley&Sons, New Jersey, 2011.
4. Hamblen J.O., Hall T.S., Furman M.D., **Rapid Prototyping of Digital Systems**, Springer, 2007

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**INTEGRATED TIRE DEVELOPMENT**
Professor/professors:	Miloš S. Stojković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Providing students with the necessary level of knowledge about integrated tire development in order to prepare them for future research and development in the field. This implies students being able to analyse and reconstruct the existing tire development systems for the purpose of increasing the performance, as well as to design new ones in accordance with the demands of the business system.

Course outcome

After completing the course and passing the exam, students will be able to:

- identify existing and/or required components and features of modern tire development systems,
- identify the place, reasons and conditions of IT application with the aim of information integration of tire development, decision-making support, and eventual improvement of system performance,
- apply the methods and procedures for performance measurement and optimization of integrated tire development systems, and analyse the results,
- recognize the challenges faced by modern systems of integrated tire development.
- design a computer model of integrated tire development for the purpose of simulation and performance analysis.

Course content

Theory classes

- Course introduction – integrated tire development – processes, organization and goals,
- Tire planning,
- Creation and selection of concepts,
- Tire design,
- Tire design for manufacturing,
- Tire design in the context of environmental protection,
- Manufacturing and testing of a prototype tire,
- Managing the tire development project,
- Current research areas in the field.

Guided independent research

- Conducting research with the instruction from the professor, advisor and, optionally, appointed supervisor from a tire company into the selected topic from the field of integrated tire development,
- Independent work: writing a term paper on the selected topic from the field of integrated tire development,
- Visits to modern tire development systems.

Recommended literature

1. Gent, A. N., & Walter, J. D., **The Pneumatic Tire**. Washington D.C.: National Highway Traffic Safety Administration, U.S. Department of Transportation.
2. K. Urlich, S. Eppinger, **Product Design and Development**, McGraw-Hill/Irwin, 5. ed. 2011.
3. U. Sandberg, J.A. Ejsmont, **Tyre/Road Noise Reference Book**, INFORMEX, Harg, SE-59040 Kisa, Sweden
4. Никола Коруновић**, Анализа стационарног котрљања пнеуматика применом метода коначних елемената [Steady-state rolling tire analysis using the finite element method]**, докторска дисертација, Машински факултет у Нишу
5. Selected scientific papers.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures are held in a consultative manner and through interactive cooperation with the advisor and, optionally, appointed supervisor from a tire company. The course includes guest speakers from tire manufacturing companies. GIR will be performed in cooperation with tire manufacturing companies. Furthermore, the course also includes visits to tire manufacturing plants. Project tasks should be completed outside of active teaching classes.

Knowledge assessment (maximum number of points 100)

Term paper (60) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SURFACE ENGINEERING**
Professor/professors:	Dušan Lj. Petković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective:

Acquiring new knowledge in the field of surface engineering of metallic materials.

Course outcome:

Students acquire knowledge that enables them to independently study and solve problems in the field of surface engineering of metallic materials.

Course content

- Behaviour of metallic materials subjected to various types of loading
- Nature and characteristics of surfaces of metallic and non-metallic materials
- Concept of corrosion, corrosion protection methods and methods for testing corrosion-resistance of materials
- Concept of friction and material wear
- Methods of changing the structure and properties of material surfaces
- Material coating.

Guided independent research

- Preparing students to independently research written literature and scientific journals in the field of surface engineering of metallic materials. Introduction to testing methods in the field of surface engineering.

Recommended literature

1. Зрилић Р., Добраш, Д.: **Наука о материјалима [Materials science]** – књига 1 и 2, Машински факултет Бањој Луци, 2018.
2. Callister D. William., **Materials Science and Engineering**, 7-th Ed., John Wiley & Sons, Inc., 2007.
3. Davim J. Paulo Ed., **Materials and Surface Engineering - Research and Development,** Woodhead Publishing Limited, 2012.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, laboratory exercises and term paper.

Knowledge assessment (maximum number of points 100)

Term paper (60 points) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ARCHITECTURES AND DESIGN OF INFORMATION SYSTEMS**
Professor/professors:	Milan M. Zdravković, Nikola M. Vitković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge and skills in the field of design and development of information systems.

Course outcome

Students are able to independently define the design of an information system for an effective implementation of the predicted enterprise architecture (based on the defined requirements) and produce the elements of its prototype.

Course content

Theory classes

- Enterprise architecture – reference models and modelling frameworks (Zachman framework, ISO 19439, TOGAF, DoDAF and others). Functions of enterprise resource planning (ERP)
- Model-based system and software engineering. OMG MDA standards (Meta-Object Facility, XMI, CWM, CORBA, Unified Modelling Language). Domain-specific languages (DSL) and tools for their development (Xtext). Semantic, formal models of information systems (RDF, RDFS, OWL). Data models (ER modelling)
- Requirements engineering
- Information system security (public-key architecture)
- Cooperative information systems – system integration and interoperability. Semantic interoperability
- Implementation of information systems, maturity assessment and change management
- Technologies for the development of future information systems: New interfaces (virtual and augmented reality), New architectures (Blockchain)
- Modern concepts of software engineering. Procedural and object-oriented programming. Web programming: programming languages, libraries and development frameworks, MVC pattern, front-end and back-end programming. Micro-service architecture. Platform as service (AWS, Google). Software as service (Restful API)
- Agile methodologies in software development management (Kanban, Scrum)
- Entrepreneurship in software engineering (Lean Startup concepts, elements of modern innovation ecosystems, financing)

Guided independent research

- Preparing students to independently research scientific and professional literature and other sources of information in the field of architecture and design of information systems. Creating a modern design of an information system for defined enterprise circumstances. Developing elements of information systems (web programming) by using agile methods. Attending relevant online courses.

Recommended literature

1. O'Brien, J.A., Marakes, G.M., Behl, R. (2017) **Management Information Systems**. McGraw Hill Education
2. Wagner, B., Monk, E.F. (2008) **Enterprise Resource Planning**. Cengage Learning
3. Bernard, S.A. (2012) **An Introduction to Enterprise Architecture: Third Edition**. AuthorHouse
4. Здравковић, М. (2017) **Приручник за рад са релационим базама података [Handbook for working with relational databases]**. Машински факултет у Нишу. ИСБН 978-86-6055-094-3
5. Welling, L, Thompson, L. (2006) **PHP and MySQL Web Development**. Addison-Wesley Professional
6. Ries, E. (2011) **The Lean Startup**. Crown Publishing Group

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, demonstration of software tools, practical work with students in problem solving, term paper.

Knowledge assessment (maximum number of points 100)

Term paper with defence (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**DESIGN OF BIOMEDICAL PRODUCTS**
Professor/professors:	Miloš S. Stojković, Nikola M. Vitković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Providing students with a necessary level of knowledge of advanced methods and techniques in the design of implants, aids and devices used for medical purposes, so as to enable them to conduct future research and development in the above field.

Course outcome

Students are able to independently apply the advanced methods and techniques in designing medical devices, implants and aids. Students are able to work in research institutions or companies that provide the scientific and technological support to medical institutions.

Course content

Theory classes

- Methods for acquiring and processing digital tissue geometry images (radiological and ultrasound),
- Methods for reconstructing geometry on the basis of digital tissue geometry images,
- Methods for modelling organic form geometry (surface subdivision, digital sculpting, etc.),
- Implant design and parameters
    - endoprosthesis, scaffolds, and fixation elements,
- Implant solution design and challenges
    - orthopaedic implants, dental and cranio-maxillofacial surgery implants,
    - cardiovascular stents and prosthesis (valves, branches), pacemakers,
    - spinal and neurosurgery implants, gastrointestinal stents and prosthesis,
    - ophthalmological and otological implants, implants of musculoskeletal soft tissue,
    - aesthetic surgery implants, urological implants,
- BM product model personalization,
- BM product functional optimization,
- Design of medical devices for diagnostics (x-rays, CT scanners, MRI, ultrasound sonars, mini-laboratories, personal diagnostic devices)
- Design of medical devices for treatment and interventions (defibrillators, surgical and dental instruments)
- Design of medical devices for drug administration (administering drugs through skin and by inhalation)
- Design of medical aids (orthopaedic aids, gastrointestinal catheters...)

Guided independent research

- Project task – preparing a solution design of a BM product related to the dissertation in the field of BMI
- Preparation of a term paper that should be transformed into a scientific paper to be presented at a scientific conference or published in a journal

Recommended literature

1. Joseph D. Bronzino, Donald R. Peterson **Medical Devices and Human Engineering**, (2017), (Eds.) , CRC Press, 1st Edition
2. Paul H. King, Richard C. Fries, Arthur T. Johnson, **Design of Biomedical Devices and Systems**, (2018), (Eds.), CRC Press, 4th Edition
3. Myer Kutz (Editor), **Biomedical Engineering and Design Handbook,** Volume 1 and 2, (2009), McGraw-Hill Education; 2nd Edition
4. Claudio Becchetti, Alessandro Neri, **Medical Instrument Design and Development: From Requirements to Market Placements,** (2013), , Wiley
5. John G. Webster (Editor), **Medical Instrumentation: Application and Design** (2009), Wiley, 4th Edition
6. Selected scientific papers.

John G. Webster (Editor),	Lectures	4	Guided independent research	3

Teaching methods

Lectures are held in a consultative manner and through interactive cooperation with the advisor and, optionally, appointed supervisor – a researcher within the field of medicine or employed in the industry. The course professor introduces students to the course content. After being introduced to the course content each student, in cooperation with the advisor, professor or supervisor, chooses the topic of the project task and works on it. It is expected that the final result of working on the project task will be a manuscript, recommended for presentation at an international scientific conference or published in a scientific journal.

Knowledge assessment (maximum number of points 100)

Project task (60) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MACHINE VISION**
Professor/professors:	Ivan T. Ćirić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of machine vision, development and application of machine vision algorithms.

Course outcome

Enabling students to analyse and design complex machine vision systems.

Course content

Theory classes

- Machine vision, control and monitoring,
- Computer vision, algorithm development,
- Robotic vision, perception of surroundings and robot path planning,
- Development of advanced machine vision algorithms,
- Intelligent machine vision algorithms,
- Modern trends in machine vision,
- Implementation of machine vision algorithms in complex control systems.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of machine vision.
- Design and development of machine vision algorithms.
- Implementation of machine vision systems in autonomous systems.

Recommended literature:

1. Carsten Steger; Markus Ulrich; Christian Wiedemann, **Machine Vision Algorithms and Applications**, 2nd edition, Wiley VCH, 2018.
2. E. R. Davies, **Computer and Machine Vision: Theory, Algorithms, Practicalities**, 4th edition, Academic Press, 2012.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MECHATRONIC SYSTEMS IN VEHICLES**
Professor/professors:	Miloš S. Milošević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

In the context of a multidisciplinary approach to the development of modern vehicles, the objective of this course is to enable students to critically assess different technologies and methods needed to efficiently design, model, simulate, implement, validate and verify mechatronic systems in modern vehicles.

Course outcome

The outcome of this course is the ability of students to assess different technologies and integration challenges related to the multidisciplinary approach to the development of modern vehicles based on the advantages of using mechatronic systems. The course is structures in such a way so as to provide in-depth knowledge and expertise in the analysis, synthesis and development of modern mechatronic systems and their use for the purpose of increasing safety, efficiency, performance, comfort and the environmental aspect in modern vehicles within the current research projects in this field.

Course content

Theory classes

- Definition, classification and morphology of motor vehicles.
- Historical development of mechatronic systems in vehicles. Application. Market. Mass exploitation.
- Functional principles of mechatronic systems in vehicles. Mechanical. Fluid. Thermal. Electric. Electronic. Interdisciplinarity.
- Components of mechatronic systems in vehicles. Sensors, actuators, microcomputers and electronic control units, communication protocols and networks. Diagnostic systems.
- Modern mechatronic systems in vehicles. Vehicle control, auxiliary control system, driver-vehicle interface, electronic control. Transmission control, automatic gearboxes. Braking system control, electromechanical active and adaptive braking system, anti-lock braking system and braking assistance. Dynamics of motor vehicles, vehicle stability control, electronic stability control. Sensors in tires. Diagnostic systems, remote diagnostics. Telematics. Interaction between a vehicle and other vehicles and smart infrastructure. Safety. Ecology, economy and performance. Comfort. Communication, telecommunication and navigation equipment. Hybrid and electric vehicles. Autonomous and intelligent vehicles.
- Modelling and simulation in identification, design and optimization of mechatronic systems in vehicles.
- Multidisciplinary approach to the design of mechatronic systems in vehicles. Design of mechanical parts. Design of electrical parts. Design of control and communication. Integration.
- Reliability, calibration, validation and verification of modern mechatronic systems in vehicles.
- Current research projects and modern tendencies in the application of mechatronic achievements in vehicles.

Guided independent research

- Preparing students to independently research literature with the aim of expanding their knowledge and expertise in the analysis, synthesis and development of modern mechatronic systems within current research projects in this field.

Recommended literature:

1. Милошевић, М., Тјупа, Љ., **Компоненте мехатроничких система код возила [Components of mechatronic systems in vehicles]**, Машински факултет у Нишу, Ниш, 2017.
2. James Duffy, **Modern Automotive Technology**, Goodheart-Willcox, 2013.
3. Tom Denton, **Automobile mechanical and electrical systems**, Butterworth-Heinemann, Oxford, 2011.
4. James Halderman, **Automotive technology – principles, diagnosis, and service**, Pearson education, New Jersey, 2012.
5. Group of authors, **Automotive electrics and automotive electronics**, Robert Bosch GmbH, Plochingen, 2007.
6. Amir Khajepour, Saber Fallah, Avesta Goodarzi, **Electric and Hybrid Vehicles: Technologies, Modeling and Control - A Mechatronic Approach**, Hoboken, Wiley, 2014.
7. Web references.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**OPTIMAL SYSTEMS IN MECHATRONICS**
Professor/professors:	Miloš B. Simonović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to different optimization techniques and optimal control methods, as well as with the optimization of the modern mechatronic systems itself.

Course outcome

Students will be able to independently define and solve practical optimization problems for mechatronic systems (path optimization, motion control, vibration reduction...).

Course content

Theory classes

- Formulation of optimization problems,
- Typical characteristics of optimization problems,
- Minimization without constraints,
- Minimization with constraints,
- Simpler optimization algorithms,
- Algorithms for continuous optimization with and without constraints, algorithms for linear and squared problems, convex optimization, general nonlinear optimization, deterministic methods, stochastic and heuristics methods (Monte Carlo methods, simulated annealing, evolutionary algorithms, particle theory...),
- Methods of optimal control of mechatronic systems,
- Application to optimization problems in mechatronic systems – path optimization, motion control, vibration reduction,
- Example of analysis and optimization of the influence of deviations from nominal dimensions to mechanism operation.

Guided independent research

- Formulation of an optimization problem, constraints identification, identification of an adequate optimization algorithm, and optimization of a concrete synthesis problem by using the MATLAB software (Toolbox Optimization).

Recommended literature:

1. M. Szuster, Z. Hendzel, **Intelligent Optimal Adaptive Control for Mechatronic Systems**, Springer International Publishing, 2018 ISBN 978331968826 8 (online) ISBN 9783319688244 (print) doi:10.1007/978-3-319-68826-8
2. Rao, S. S., **Engineering Optimization Theory and Practice**, John Wiley & Sons, Inc. Hoboken, New Jersey, 2009.
3. Suh, C.H., Radcliffe, C.W., **Kinematics and mechanisms design**, John Wiley, 1978.
4. Erdman, G. A., Sandor, N. G., **Mechanism Design - Analysis and Synthesis**, Prentice Hall, New Jersey, 1997.
5. J. Nocedal, S. Wright, **Numerical Optimization**, Springer, New York, 1999.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**INTELLIGENT SENSOR AND ACTUATOR SYSTEMS**
Professor/professors:	Jelena Ž. Manojlović, Aleksandra M. Cvetković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course objective is to expand the knowledge in the filed of intelligent actuators and sensors, with a particular emphasis on their application. Examples of modelling, design and simulation of intelligent structures will be described. Students will be introduced to networking technologies for intelligent sensors and actuators.

Course outcome

The course outcomes are the knowledge and ability of students to perform individual and team scientific work in the field of intelligent sensor and actuator systems. Students will understand intelligent sensors and actuators, mathematical models used to describe their operation. They will also be introduced to modern networking technologies for sensors and actuators, and their integration into modern IoT systems.

Course content

Theory classes

- Smart materials in the manufacture of small dimension systems (MEMS and NEMS) and the principles of their construction.
- Integration of intelligent sensors and actuators into intelligent structures.
- Modelling, design and simulation of intelligent structures.
- Application of intelligent actuators and sensors in robotics, biotechnology, medicine, automotive industry...
- Networking layers of intelligent systems.
- Integration of intelligent systems into IoT (Internet of Things).

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of intelligent actuators and sensors.

Recommended literature:

1. Gaura, E., Newman, R., **Smart MEMS and Sensor Systems**, Imperial College, 2006.
2. Pawlak, A. M., **Sensors and Actuators in Mechatronics**, CRC Press, 2006.
3. De Silva, C. W , **Sensors and Actuators Engineering System Instrumentation**, Taylor & Francis, 2015.
4. Kim, D.-S., Tran-Dang, H., **Industrial Sensors and Controls in Communication Networks: From Wired Technologies to Cloud Computing and the Internet of Things**, Springer, 2019.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MODELLING AND SIMULATION OF LOGISTIC SYSTEMS**
Professor/professors:	Predrag Đ. Milić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the needs for modelling and simulation of logistic processes, as well as to various types of simulations in different areas of logistics.

Course outcome

Students acquire theoretical and practical knowledge that enables them to independently study and solve problems in modelling and simulation of logistic systems.

Course content

Theory classes

- Basic simulation terms (real system, model, simulation model, simulation, analysis of simulation results).
- Random numbers and generators of random numbers. Test of randomly generated numbers. Modelling a random variable quantity over empirical and theoretical distribution. Analysis of simulation data.
- Monte Carlo simulation. Types of Monte Carlo simulation. Techniques of variance reduction. When to use the Monte Carlo method. Method advantages and disadvantages.
- Simulation models in queueing theory: Structure and properties of a queueing theory model. Queueing networks.
- Discrete event simulation: Basic terms and properties of discrete simulation models. Concepts and components of discrete simulation models.
- Agent-based simulation. Types of agents. Multiagent models. Simulation – system dynamics.
- Stock system simulation. Supply chain simulation.
- Continuous transport: Simulation analysis in the examples of continuous transport.
- Simulation systems: Simulation software overview.
- Examples of modelling with commercial software packages. Simulation analysis performance. Task and objective formulation. Experiments with simulation models.
- Simulation data analysis. Distribution assessment and tests.
- Verification, calibration and validation of simulation models.
- Modern trends in simulation development.

Guided independent research

- Preparing students to independently research written literature, professional and scientific journals and web portals in the field of modelling and simulation of logistic systems. Laboratory research.

Recommended literature

1. Law A.,: **Simulation modeling and analysis**: Mcgraw-hill Series in Industrial Engineering and Management, 2014.
2. Петровић Г., Милић П., Мадић М.: **Квантитативна логистика - вероватноћа, статистика и случајни процеси са применом [Quantitative logistics – probability, statistics and random processes with application]**, Машински факултет Универзитета у Нишу, Ниш, 2018.
3. Banks J., Carson, J.: **Discrete-Event System simulation**, Perason Education. Inc., 2010. ISBN: 978-0-13-606212-7
4. Susmita B., Ranjan B.: **Discrete and Continuous Simulation Theory and Practice**, Taylor & Francis Group, LLC, 2014. ISBN: 978-1-4665-9640-5
5. Maquardt H.G., **Симулације логистичких транспортних система [Simulation of logistic transport systems]**, превод предавања, TU Dresden, Машински факултет Ниш, 2004.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**NONLINEAR FEM STRUCTURAL ANALYSIS IN TRANSPORT ENGINEERING**
Professor/professors:	Dragan Z. Marinković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Expanding the knowledge acquired at undergraduate studies related to the structural analysis of carrying structures in the field of transport engineering, understanding the causes of nonlinear deformational behaviour and, accordingly, the distinction between different types of nonlinear analysis, FEM formulations for nonlinear structural analysis and algorithms for solving nonlinear problems, identification of the cases from the field of transport engineering that require nonlinear structural analysis.

Course outcome

Students acquire basic knowledge in nonlinear FEM structural analysis, which enables them to comprehend the differences between the linear and nonlinear FEM analysis, identify the cases that require application of nonlinear structural analysis and understand the basic steps in performing a nonlinear FEM structural analysis.

Course content

Theory classes

- Fundamental elements of linear FEM structural analysis, applied assumptions and their consequences.
- Steps in performing linear and nonlinear FEM structural analysis and their comparison. Causes and types of nonlinearities – geometric, material, contact.
- Algorithms for solving nonlinear FEM problems. Tangential stiffness matrix. Incremental approach. Linearization of the problem and iterative solution procedure – Newton-Raphson method, modified Newton-Raphson method, arc/line search method.
- Geometrically nonlinear analysis. Formulations of nonlinear FEM analysis – total Lagrange, updated Lagrange, corotational formulation. Strain and stress measures. The effect of stress state – geometric stiffness matrix. Structural stability, post-buckling deformational behaviour. Follower forces. Examples from the field of transport engineering.
- Materially nonlinear analysis. Description of material properties dependent on strain and strain rate. Elastic-plastic material behaviour. Examples from the field of transport engineering.
- Contact problems. Manners of solution. Examples from the field of transport engineering.
- Combination of the approaches based on Multi-Body System (MBS) and FEM to resolve nonlinear problems in the field of transport engineering. Decomposition of overall motion into the rigid-body motion and deformable motion.
- Local nonlinearities. Model sub-structuring. Examples from the field of transport engineering.

Guided independent research

- Computer exercises using modern FEM software packages.

Recommended literature

Basic:

1. Bathe K. J.: **Finite element procedures**, Prentice Hall, New Jersey, 1996.
2. **Getting started with ABAQUS**, Dassault Systems Simulia Corp.

Additional:

Material from lectures.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper.

Knowledge assessment (maximum number of points 100)

Independently written term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SIMULATION AND OPTIMIZATION OF INTERNAL COMBUSTION ENGINE OPERATION**
Professor/professors:	Jovan Ž. Dorić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Acquiring new knowledge of the role and importance of modelling dynamic processes in internal combustion engines (ICE). Expanding theoretical knowledge in the field of applied thermodynamics, heat and mass transfer, fluid mechanics, fuel combustion by studying dynamic processes in cylinders, collectors and flow channels in ICE for the purpose of optimizing engine operation and its simulation.
- Enabling students to independently and on scientific basis study and solve problems of ICE operation optimization as well as simulation of working processes in engines, related to the preparation of the doctoral dissertation.

Course outcome

Acquiring necessary knowledge in optimization and simulation of working processes in ICE, which will be used both in scientific research and in modelling, design, calculation and construction of ICE.

Course content

Theory classes

- Introductory considerations.
- Basics of creating an ICE model.
- Simulation of heat transfer and thermodynamic characteristics of operating matter.
- Combustion models.
- Simulation of processes in intake and exhaust collectors.
- Engine dynamics.
- Importance of mathematical modelling and computer simulation of the working process for structural optimization and improvement of performance, energy and environmental engine characteristics.
- Differential equations of the so-called “zerodimensional” model of the working process for the engine workspace as an open thermodynamic system on the basis of the first and second law of thermodynamics and the law of conservation of mass.
- Modelling heat transfer with the engine workspace walls.
- Modelling the combustion process (heat release) in the engine. Types of heat release models in zerodimensional modelling of the working process.
- ICE performance optimization.
- Simulation of ICE characteristics.

Guided independent research

- Preparing students to do research within their doctoral dissertation, by writing a term paper that deals with the problems in engine simulation and optimization, in line with the problem presented in the doctoral dissertation.

Recommended literature

1. Дорић J.: **Теорија Мотора СУС [IC engines theory]**, Факултет техничких наука, Нови Сад, 2015.
2. Merker G., Schwarz C., Stiesch G., Otto F.: **Simulating Combustion**, Springer-Verlag Berlin, Heidelberg, Germany, 2006.
3. Basshuysen R.: **Otto motor mit Direktein spritzung-Verfahren, Systeme, Entwicklung, Potenzial**, Vieweg, Germany, 2007.
4. Benson R.S.: **The Thermodynamik and Gasdynamik of Internal Combustion Engines**, Clarendon Press, Oxford, 1982.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**NUMERICAL SIMULATION OF FLUID FLOW**
Professor/professors:	Miloš M. Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Convey the course content on the methodology of numerical simulations of fluid flow.
- Convey the experience and teach students how to independently use adequate software.

Course outcome

- Adopted knowledge in the field methodology of numerical simulations of fluid flow.
- Acquired skills in using CFD software and using the methodology of numerical simulations.

Course content

Theory classes

Concept of software for numerical simulation of fluid flow

- Formulation of the physical model of the process. Formulation of the mathematical differential model of the process. Formulation of the numerical model of the process. Calibration and validation of the model. Extrapolation of the model.

Structures of modern software for numerical fluid mechanics

- Basic structure.
- Functional elements of preprocessing.
- Generating a numerical mesh, control volume types, density criterion and numerical solution independence of the generated mesh.
- Defining physical values, boundary conditions, initialization, defining of numerical parameters, defining of output data.
- Functional elements of processing (choosing the flow model, type of solver, monitoring of solution convergence, solution convergence criterion).
- Steady and unsteady numerical simulation of fluid flow, boundary conditions, initial conditions, time step, dynamics of process, selection of appropriate models.
- Functional elements of postprocessing (formats of output data, graphical postprocessing).
- Representation of results (figures and diagrams). Creating animations based on the results of unsteady simulations.

Numerical simulations of fluid flow

- Two-dimensional and three-dimensional geometric domains. Simulations of laminar and turbulent fluid flow. Problems of flow around bodies. Attaching different flow domains, modelling of contact surfaces. Changing the flow domain, moving domains, changing of numerical mesh.
- Simulations of unsteady flow processes, simulations of compressible fluid flows, shock waves.
- Simulation of fluid flow in rotational domains.
- Two-phase flow models – cavitation problems (valves and flow around the steady surfaces).

Accuracy of numerical simulations

- Optimal choice of the model. Choice of the solver, discretization schemes and algorithms.
- Defining additional values. Defining the mesh influence on the numerical solution.
- Problems of numerical solution convergence. Possibility of solving the problem.

Guided independent research

- Preparing students to work in adequate software as part of their doctoral dissertation by writing two term papers on the topics directly correlated with the problem presented in the doctoral dissertation.

Recommended literature

1. Joel H. Ferziger, Milovan Peric, **Computational Methods for Fluid Dynamics**, Springer, 2002.
2. John D. Anderson, **Computational Fluid Dynamics: The Basics with Applications**, McGraw Hill, 1995.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MAGNETOHYDRODYNAMICS**
Professor/professors:	Živojin M. Stamenković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquire knowledge in the field of modern fluid mechanics, which is related to the phenomena that are present in the flow of electrically conducting fluids. Prepare doctoral students for theoretical analysis of such problems, as well as practical application of acquired knowledge to solving tasks that appear in MHD problems.

Course outcome

Acquired necessary up-to-date knowledge related to phenomena of steady and unsteady flows of electrically conducting fluids in a magnetic field. Doctoral students who take this course acquire skills for theoretical analysis and application of acquired knowledge to different problems in magnetohydrodynamics (MHD pumps, MHD generators, flow meters, flow control, etc.).

Course content

Theory classes

- Preliminaries
- Electrical conductivity of working fluids
- Magnetohydrodynamics of electrically conducting gases
- Basic equations of magnetohydrodynamics, magnetic induction, non-dimensional parameters
- Electrical equations and Ohm law, Lorentz force, Hall effect, General Ohm law
- Basic characteristics of flow, flow in conducting ducts, Hartmann flow
- MHD fluids
- Flow in closed channels, fully developed flow in a channel
- Flow development, variable fields, variable channel sizes, the effect of inlet
- Flow in channels with a variable magnetic field
- Flow in open channels
- Turbulent MHD flows
- MHD two-phase flow - flow characteristics
- Power generation through MHD technology, efficiency
- MHD pumps and flow meters, conduction MHD pumps, MHD induction pumps
- MHD generators
- Experimental and numerical exercises in line with the course content

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate model considered in the problem presented in the doctoral dissertation.

Recommended literature

1. Davidson, P.A. **An introduction to Magnetohydrodynamics**, Cambridge University Press, 2001
2. Muller, U. Buller, L, **Magnetohydrodynamics in channels and containers**, Springer, 2001.
3. Roberts, P.H, **An Introduction to Magnetohydrodynamics**. New York: Elsevier, 1967.
4. Freidberg P. Jeffry, **Ideal Magnetohydrodynamics**, Massachustets Institute of Technology, Cambridge, 2000.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**UNSTEADY AND UNSTABLE TURBOMACHINERY FLOW**
Professor/professors:	Jasmina B. Bogdanović-Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge in the field of unsteady and unstable turbomachinery flow. Enabling students to independently and on scientific principles formulate unsteady and unstable flow phenomena.

Course outcome

Students gain knowledge in the field of unsteady and unstable turbomachinery flow and acquire skills in the methodology of describing unsteady and unstable turbomachinery flow phenomena.

Course content

Theory classes

- General characteristics of unsteady fluid motion through turbomachinery cascades
- Classification of unsteady flows in turbomachinery
- Unsteady flow through cascades
- Mutual influence of cascades
- Oscillating of turbomachinery blades
- Cavitation phenomenon
- Development of cavitation in steady flow
- Global stability
- Pumping phenomenon, Unsteady cavitating flow
- Pumps and turbines cavitation
- General characteristics of unstable fluid flow through turbomachinery
- Conditions for formation of unstable flow
- Classification of unstable turbomachinery flow
- Flow instability caused by uneven distribution of flow parameters per volume
- Unstable flow caused by the loss of global stability
- Rotating stall phenomenon
- Theoretical study of unstable phenomena in turbomachinery
- Experimental study of unstable phenomena in turbomachinery
- Expanding the area of stable operating modes for pumps, compressors and fans
- Influence of turbomachinery geometry on the occurrence of unstable operating regimes.

Guided independent research

Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the considered adequate unstable or unsteady flow phenomenon in turbomachinery.

Recommended literature

1. Meinhhard Schobeiri, **Turbomachinery flow physics and dynamic performance**, Springer, 2005.
2. Turton R.K., **Principles of Turbomachinery**, Chapmann & Hal, 1995.
3. Миленковић Д., **Нестабилни радни режими турбомашина [Unstable turbomachinery operating regimes]**, Машински факултет Ниш, 1999.
4. Christopher E. Brennen, **Hydrodynamics of pumps**, Oxford University Press, 1994.
5. Samoilovič G. S., **Nestacionarnoe obtekanie i aerouprugie kolebania rešetok turbomašin**, Izdatelstvo nauka F.M.L. Moskva, 1969.
6. Stepanov G. JU., **Gidrodinamika tešetok turbomašin**, F.M.L. Moskva, 1962.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF NON-NEWTONIAN FLUID FLOW**
Professor/professors:	Jelena D. Petrović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the theory of non-Newtonian fluid flow.

Course outcome

Students acquire knowledge that enables them to independently study and solve different problems related to non-Newtonian fluid flow.

Course content

Theory classes

- Principles of continuum mechanics. Basic terms. Material derivative. Deformation velocity. Rivlin-Ericksen tensors. Stress tensors. Steady flow kinematics. Planar flow. Poiseuille flow. Couette flow. Continuity equation. Volumetric force and stresses. Equations of motion. Energy equation.
- Fluid properties in steady flow. Stream function. Normal stress function.
- Process control by stream function. Rotational viscometer. Dissipation effect. Flow in a straight channel.
- Flow between cylinders. Flow in pipes. Flow in bearings.
- Effect of difference between normal stresses. Weissenberg effect. Slip flow.
- Simple unsteady flow. Linear viscoelasticity. Abrupt changes in shear velocity. Flow around an oscillating wall.
- Rayleigh problem for Maxwell fluid. Unsteady Couette flow. Nonlinear effects of unsteady flow in a pipe. Constitutive equations for slow-changing processes. Flow in a planar boundary layer. Boundary layer separation point. Lubrication theory.
- External flows. Theoretical principles. Application.
- Special rheological laws. Fluids without memory. Integral models of flow between eccentric rotating discs. Differential models.
- Secondary flows. General theory. Planar flow around a rotating body.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the theory of non-Newtonian fluid flow.

Recommended literature

1. G. Böhme, **Non-Newtonian Fluid Mechanics**, Elsevier Science Ltd (1987).
2. R. P. Chhabra, J. F. Richardson, **Non-Newtonian Flow and Applied Rheology**, Elsevier (2008).
3. Emil-Alexandru Brujan, **Cavitation in Non-Newtonian Fluids**, Springer-Verlag Berlin Heidelberg (2011).

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN PROJECT MANAGEMENT**
Professor/professors:	Miloš D. Milovančević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course objective is for students to master modern approaches to project management and specific knowledge necessary for successful project implementation. In classes student will be introduced to modern techniques and tools for process integration, time, cost, quality, communication, risk and supply management, but also procedures for the development and improvement of existing approaches, tools and techniques in project management.

Course outcome

Students who complete this course and pass the exam are able to independently and clearly gain an insight into the advanced understanding of research, methodology and approaches in the selected field; to compare and analyse principles within several theoretical traditional and modern approaches in the field of complex project management, employ modern approaches, tools and techniques, and conduct scientific research in the given field; to show research capabilities in the critical examination of relations between theoretical explanations, methods, research problems and issues, and empirical data in the selected field; to apply the acquired knowledge and techniques to analyse certain research in the field.

Course content

Theory classes

- New approaches in project management,
- Modern techniques and tools in project management,
- Project management in accordance with internationally recognized standards,
- Software packages for project management,
- Lean project management,
- Change management,
- Development of tools and techniques in project management,
- Agile methods in project management.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of project management.

Recommended literature

1. Miloš Milovančević, Dragan Milčić, Boban Anđelković, **Projektni menadžment [Project management]**, **-** Niš: Mašinski fakultet, 2015, ISBN 978-86-6055-069-1.
2. Miloš Milovančević, **Upravljanje ljudskim resursima u inženjerskom menadžmentu [Human resource management in engineering management]**, **-** Niš: Mašinski fakultet, 2015, ISBN 978-86-6055-085-1
3. Biljana Marković, Miloš Milovančević, Dejan Jeremić, **Upravljanje razvojinim projektima [Development project management]**, – Banja Luka: Mašinski fakultet, 2015, ISBN 978-99976-623-5-4

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MODELLING IN THERMAL ENGINEERING, THERMOENERGETICS AND PROCESS ENGINEERING**
Professor/professors:	Mirjana S. Laković Paunović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to the course content on modelling of objects and processes in energy and process engineering.
- Enabling students to formulate independently and on scientific principles an appropriate mathematical model of the presented problem, which is related to the preparation of the doctoral dissertation.

Course outcome

- Acquired knowledge from the theory of models and prototypes.
- Acquired skills related to the methodology of measuring and testing the characteristics of equipment in thermal engineering, thermoenergetics and process engineering.

Course content

Theory classes

- Dynamics of objects and processes,
- Dynamics of flow processes,
- Mathematical models of flow processes with focused parameters,
- Mathematical models of flow processes with distributed parameters,
- Deterministic and stochastic processes,
- Dynamics of flow-thermal processes,
- Dynamics of machines and motors,
- Dynamics of energy plants,
- Dynamics of thermal engineering plants,
- Dynamics of thermal energy plants,
- Dynamics of process plants.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the considered adequate problem of the task presented in the doctoral dissertation.

Recommended literature

1. Dragutin Debeljković, **Dinamika objekata i procesa [Dynamics of objects and processes]**, Mašinski fakultet Beograd, 1989.
2. Caldwell J., Douglas K.S., **Mathematical modeling-case studies and projects**, Kluwer Academic Publisher, 2004.
3. Roger W. Haines, Douglas C. Hittle, **Control systems for heating, ventilating and air conditioning**, Springer, 2003.
4. Webster G. John, **Measurement, Instrumentation, and Sensors Handbook**, CRC Press LLC, 2000.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (75 points) and oral exam (25 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**NUMERICAL SIMULATION OF TRANSPORT PROCESSES IN THERMAL ENGINEERING, THERMOENERGETICS AND PROCESS ENGINEERING**
Professor/professors:	Predrag M. Živković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	Passed exam in Numerical Methods

Course objective

- Introducing students to the course content on the methodology of numerical simulations in thermal flow processes.
- Enabling students to independently use appropriate software.
- Conveying the experience of using appropriate software.

Course outcome

- Adopted knowledge in the field of numerical simulations in energy and process engineering.
- Acquired skills in using appropriate software.
- Acquired skills in using the methodology of numerical simulations.

Course content

Theory classes

Concept of software process prototype in energy and process engineering

- Formulation of the physical model of the process. Formulation of the mathematical differential model of the process. Formulation of the numerical model of the process. Calibration and validation of the model. Extrapolation of the model.

Structures of modern software for numerical fluid mechanics, heat and mass transfer

- Basic structures. Modular concept of software. Functional elements of preprocessing (generating numerical mesh, defining physical values, boundary conditions, initialization, defining of numerical parameters, defining of output data). Functional elements of processing (choosing of the solver type, using open source code and closed modules, monitoring of solution convergence, solution convergence criterion). Functional elements of postprocessing (formats of output data, graphical postprocessing, graphical representation of results, numerical animations).

Specificities of numerical simulations in energy and process engineering

- Characteristic geometries (boilers, furnaces, burners, heat exchangers, pumps, filters, conveyor components, etc.). Selection of turbulent models. Selection of two-phase flow models. Selection of combustion models. Selection of radiation models.

Strategies to improve the accuracy of a numerical simulation

- The concept of numerical mesh (unstructured networks, sub-grid meshes, solid structure models, etc.). The optimal choice of the model (turbulence, two-phase flow, combustion, radiation). The optimal choice of solvers, discretization schemes and algorithms. User intervention in the open source code of commercial software (PHOENICS, FLUENT, ANSYS CFX).

Economic indicators of numerical simulations

- A comparative analysis of the accuracy and reliability of numerical and experimental results. Advantages and disadvantages of numerical simulations. Research costs.

Guided independent research

- Preparing students to use appropriate software by writing two term papers on the topics directly correlated with the problem presented in the doctoral dissertation.

Recommended literature

1. Žarko M. Stevanović, **Numerički aspekti prenošenja impulsa i toplote [Numerical aspects of momentum and heat transfer]**, Mašinski fakultet, Univerzitet u Nišu, ISBN 978-86-80578-81-3, (2008).
2. Miroslav Sijerčić, **Matematičko modeliranje kompleksnih turbulentnih transportnih procesa [Mathematical modelling of complex turbulent transport processes]**, Institut za nuklearne nauke - Vinča, ISBN 86-7877-005-8, (1998).
3. Technical guidelines for the use of appropriate software (PHOENICS, FLUENT, ANSYS CFX).

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term papers (two term papers, 25 points each).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**OPTIMIZATION OF ENERGY SYSTEMS AND PROCESSES**
Professor/professors:	Mirko M. Stojiljković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Expanding students' knowledge of the theoretical and practical aspects of mathematical optimization of energy systems and processes. Enabling students to perform mathematical modelling, define and solve problems in optimization of energy systems and processes.

Course outcome

Students acquire knowledge of optimization methods, details of formulating optimization problems in energy engineering and techniques for their solution. Students also gain competence in solving optimization problems in scientific research and as part of their work on the doctoral dissertation.

Course content

Theory classes

- Optimization tasks in energy systems and processes. Optimization criteria. Optimization levels in energy engineering. Constraints and goal function.
- Basic optimization principles. Convex problems. Linear programming. Decomposition of optimization problems. Nonlinear programming. Dynamic programming. Mixed whole number problems. Metaheuristics methods.
- Mathematical modelling: definition of linear optimization problems in energy engineering. Importance. Advantages and disadvantages. Interpretation of optimization results. Sensitivity analysis.
- Mathematical modelling: definition of mixed whole number linear problems in energy engineering. Importance. Performance.
- Multicriteria optimization. Epsilon-constraint method.
- Energy problems with several optimization levels. Hybrid optimization techniques.
- Dynamic problems with a moving horizon of optimization in energy engineering.
- Uncertainty and stochastic optimization problems in energy engineering.
- Application of fuzzy logic in formulating optimization problems in energy engineering. Alpha-secant method.
- Local and exhaustive search. Application of heuristic rules in energy engineering.
- Use of machine learning methods and data mining in optimization.
- Optimization of energy supply systems. Cogeneration. Trigeneration. Energy storage.
- Optimization of industrial plants.
- Optimization of heat exchanger networks. Pinch method.
- Inverse problems of heat transfer and metaheuristic solutions.
- Optimization tools in the Python programming language.

Guided independent research

- Preparing students to independently research scientific and professional literature
- Optimization preparation: mathematical modelling of energy systems
- Software solutions for optimization (Calc, Python/SciPy, Python/GLPK, Python/GurobiOptimizer)

Recommended literature

1. Vanderbei R.J**., Linear Programming: Foundations and Extensions**, Springer, 2014.
2. Boyd S, Vandenberghe L., **Convex Optimization**, Cambridge University Press, 2009.
3. Dréo J., Pétrowski A., Siarry P., Taillard E., **Metaheuristics for Hard Optimization**, Springer-Verlag Berlin Heidelberg, 2006.
4. Rao S.S., **Engineering Optimization: Theory and Practice**, Fourth Edition, John Wiley & Sons, Inc., 2009.
5. Bejan A., Tsatsaronis G., Moran M., **Thermal Design and Optimization**, John Wiley and Sons, Inc., 1996.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, supervision, term papers, guided independent research.

Knowledge assessment (maximum number of points 100)

Term paper (30 points), guided independent research (40 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF NONLINEAR VIBRATION**
Professor/professors:	Julijana D. Simonović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring the necessary knowledge of the theory of nonlinear dynamics of mechanical systems.
The objective of the course is to enable students to use all of the essential elements of nonlinear vibration: problem formulation – modelling, solution and result analysis with a required degree of clarity and logical reasoning.

Course outcome

Acquiring knowledge and skills in theoretical and analytical thinking about scientific knowledge, insights and empirical research in more complex models of nonlinear dynamics of mechanical engineering systems and structures.

Course content

Theory classes

- Differential equations and dynamic systems. Linear and nonlinear systems.
- Van der Pol's equation. Duffing's equation.
- Local bifurcation.
- Averaging methods and perturbation method.
- Approximate methods of nonlinear mechanics (Krylov, Lyapunov, Lindstat, van der Pol, slowly varying amplitude method, asymptotic methods of Krylov-Bogolyubov-Mitropol'skii and others).
- Phase plane method, phase trajectories, singular points, homoclinic orbits.
- Equilibrium stability and vibration. Lyapunov's theorem on stability and first and second order Lyapunov's function. The stability limit of orbit. Stability testing using the differential equations of the first approximation.
- Lyapunov's systems, conservative systems and geometric discussion of energy curves in the phase plane.
- Forced nonlinear vibration. Application of asymptotic methods. Amplitude-frequency and phase-frequency curve. Nonlinear phenomena and nonlinear modes of dynamics of mechanical systems. Resonant leaps and bifurcations.
- Self-excited vibrations and rheolinear vibrations. Hill's differential equation and solutions. Mathieu's differential equation and application examples. Parametric resonance condition.
- Nonlinear vibration systems with more degrees of freedom vibrations. Single-frequency and multi-frequency modes of vibration systems with more degrees of freedom.

Guided independent research

- Writing a term paper with original research results.

Recommended literature

1. Rašković, D., **Teorija oscilacija [Vibration theory]**, Naučna knjiga, Beograd.1965.
2. Bogoljubov N., Mitropoljskij Y.A., **Asimptotičeskije metodi v teorii nelinjejnih kolebanjij [Asymptotic methods in the theory of nonlinear vibration]**, Naukovadumka, Kiev, 1970. (or more recent issues in English)
3. Steven H. Strogatz (2000). **Nonlinear dynamics and chaos; with applications to physics, biology, chemistry, and engineering**. Cambridge, Mass, Westview.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, consultations, theoretical and empirical-numerical research on the model of a nonlinear mechanical system of choice.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**VIBRATION AND STABILITY OF ELASTIC BODIES**
Professor/professors:	Vladimir S. Stojanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the basics of the theory of vibration and stability of continuous elastic bodies.

Course outcome

Acquiring knowledge in theoretical mechanics.

Course content:

Theory classes

- п-version of the finite element method.
- Geometric nonlinearities of elastic body vibrations.
- Vehicle motion stability.
- Stability of Mathieu-Hill equations.
- Influence of damping on Mathieu - Hill equations.
- Stability of linear differential equations with periodic coefficients.
- Stability of Mathieu's equation.
- Approximate methods.
- Averaging methods.
- Method of multiple scaling.
- Non-gyroscopic systems with more degrees of freedom.
- Gyroscopic systems with two degrees of freedom.
- Gyroscopic systems with more degrees of freedom.
- Nonlinear systems with periodic impulses.
- Pendulum effect of the harmonic excitation at the pivot point.
- Column at the effect of the harmonic axial load.
- Vibration on initial deflection.
- Systems with more degrees of freedom.
- Examples.

Guided independent research

- Preparing students to do research within their doctoral dissertation.

Recommended literature

1. Vladimir Stojanović, Predrag Kozić, **Vibrations and stability of complex beam systems**, Springer International Publishing Switzerland, pp 166, ISBN 978-3-319-13766-7, 2015.
2. Wei-Chau Xie, **Dynamic Stability of Structures**, Cambridge, University Press, 2006.
3. Frýba, L., **Vibration of Solids and Structures under Moving Loads**, Springer, Netherlands, 1972.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Theory classes, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**TRIBOLOGY OF MECHANICAL SYSTEMS**
Professor/professors:	Dušan S. Stamenković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Enabling students to independently and based on scientific principles analyse mechanical systems from the tribological aspect.

Course outcome

Students acquire knowledge in the field of tribology of mechanical systems, which can be applied in the analysis of mechanical systems from the tribological aspects, as well as in the independent design of measuring points for determining the influence of tribological parameters.

Course content

Theory classes

- The role and importance of the friction process in mechanical systems. External and internal friction. Sliding friction. Rolling friction. Solid bodies contact. Calculation and measurement of contact parameters.
- External friction of solids. Static and kinetic friction. Pre-sliding and the importance of static friction. Parameters affecting friction. Methods for determining friction parameters: numerical and experimental. Phenomena and processes that accompany the friction process. Negative and positive effects of the friction process.
- Wear. Types of wear: fatigue, abrasive, adhesive. Theories of wear: energy, fatigue. Wear parameters; methods for determining wear parameters: numerical and experimental. Methods for increasing of wear-resistance: design, technological. Mass transfer during wear.
- Lubrication. Function, importance and significant parameters. Basic forms and types of lubrication. The general division of lubricants. Additives. Choosing the lubricant type.
- Tribological phenomena and processes in mechanical systems. Moving and fixed tribomechanical joints in mechanical systems. Gear friction. Bearings, joints and other moving elements. Press fit joints.
- Friction modelling. Modelling of tribological pairs. Friction simulation. Experimental investigation of tribological parameters. Design of measuring points to determine the influence of tribological parameters.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of tribology of mechanical systems.

Recommended literature

1. Б. Ивковић, А. Рац: **Трибологија [Tribology]**, Југословенско друштво за трибологију, Крагујевац 1995.
2. С. Танасијевић: **Триболошки исправно конструисање [Proper tribological design]**, монографија, Крагујевац 2004.
3. Д. Стаменковић, М. Ђурђановић: **Трибологија пресованих спојева [Tribology of press fit joints],** монографија, Машински факултет Ниш, 2005.
4. F. Bowden, D. Tabor: **Friction – An Introduction to Tribology**, Florida USA 1982.
5. И.В. Крагелски: **Трение и износ**, Машгиз, Москва, 1962.
6. H.D.Buckley: **Surface effects in adhesion, friction, wear and lubrication**, Elsevier Scientific Publishing Company, Amsterdam-Oxford-New York, 1981.
7. K. Budinski: **Friction in machine design**, Symposium on Tribological Modeling for Mechanical Designers, San Francisco USA 1990.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Lectures, term test and term paper.

Knowledge assessment (maximum number of points 100)

Term test (35 points), term paper (35 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**RELIABILITY OF MECHANICAL SYSTEMS**
Professor/professors:	Dragan S. Milčić, Miroslav M. Mijajlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course objective is to offer a comprehensive insight into the problems of system effectiveness, primarily in the field (analysis and design) of the reliability of technical systems.

Course outcome

After a successful completion of this course, students should be able to: explain concepts of system effectiveness, reliability and failure; analyse obtained data on the time from functional operation to failure; apply the laws of probability and statistics to calculate the operational reliability of a system; obtain theoretical distribution density and reliability function on the basis of the empirical data on element failure; determine the reliability of a complex system on the basis of the reliability of the elements that comprise such a complex system; form a fault tree of a technical system and analyse it; apply the calculation of machine elements on reliability basis.

Course content

Theory classes

Introductory consideration. Importance of reliability, basic terms, history of the development of reliability. Elements and definitions of the reliability of technical systems. Theoretical basis of reliability. Reliability function. Characteristic functions in reliability theory. Failure frequency function, cumulative failure frequency function, reliability function and failure intensity function. Distributions: exponential, normal, log-normal, Weibull, Student's distribution. Trust interval, hypothesis check. Mathematical and other methods, techniques and models in reliability. Reliability of a renewable element. Reliability of time-dependent and time-independent systems. System reliability and Markov theory. Determining distribution parameters. System structures. Systematic monitoring of the behaviour of technical systems in exploitation and basics of monitoring results analysis. Reliability aspects in system lifecycle. Reliability and system control. Reliability and maintenance engineering. Concept of system effectiveness, availability, readiness, safety of functioning. Tree analysis, failure mode and effect analysis, and failure cause analysis. Weak points in a system. Reliability allocation. Design on reliability basis. Information systems in the function of reliability assurance. Development and application of reliability models according to their purpose in technical systems – in the selected field (topic): product development, optimization, system maintenance, system adaptation, exploitation, decision-making on reliability basis. Other reliability fields – according to the needs, requirements and agreements with students (Monte Carlo, FMA, FMCA, FTA, etc.).

Practice classes

Computer exercises are fully adapted to lectures.

Recommended literature

1. Милчић Д.: **Поузданост машинских система [Reliability of mechanical systems]**. Универзитет у Нишу **-** Машински факултет, Ниш, 2005. с.200.
2. Милчић Д., Мијајловић М.: **Поузданост машинских система – Збирка решених задатака [Reliability of mechanical systems – collection of solved tasks]**, Универзитет у Нишу - Машински факултет, Ниш, 2008. с.220.
3. O'Connor, Patrick D T. and Kleyner, Andre**: Practical Reliability Engineering. Chichester**: Wiley, 2012.
4. Dimitri Kececioglu: **Reliability Engineering Handbook** Vol.1 and Vol.2, 2002.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures, term papers, project tasks.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points or written exam) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADVANCED FLEXIBLE MANUFACTURING SYSTEMS**
Professor/professors:	Vladislav A. Blagojević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of flexible manufacturing systems in accordance with the Industry 4.0 philosophy.

Course outcome

Students acquire knowledge that enables them to independently study and solve problems in the domain of flexible manufacturing systems.

Course content

Theory classes

- Introductory considerations.
- Manufacturing systems. Basics of production strategy. Automated production. Elements of automation.
- Mechanization of parts handling. Technology and equipment for material processing.
- Numerical control (CNC systems) and CAD/CAM tools and integrated software packages for product and technology design.
- Industrial robots. Design. Robot movement control. Sensors. Robot end devices. Robot programming.
- Flexible transport systems. Automated guided vehicles (AGV). Movement planning.
- Flexible storage systems.
- Machine vision systems.
- Industrial logic automation. Programmable logic controllers (PLC).
- Real-time computer control. Computers for process control. Types of process control.
- Industrial interfaces. Design of flexible manufacturing cells.
- Flexible manufacturing systems in Industry 4.0.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of flexible manufacturing systems.

Recommended literature

1. Стојиљковић М., **Логичка синтеза пнеуматских система [Logic synthesis of pneumatic systems]**, Машински факултет Ниш, Ниш, 2009.
2. Godse A.P., Godse D.A., **Digital System Design**, Technical Publication Pune, Pune, 2008.
3. Mikell P. G., **Automation, Production Systems, and Computer-Integrated Manufacturing**, Pearson, 2008
4. Tetzlaff A.W., **Optimal Design of Flexible Manufacturing Systems**, Springer, 2013.
5. Calisir F., Akdag H.C., **Industrial Engineering in the Industry 4.0 Era**, Springer, 2017.
6. Colins K., **PLC Programming for Industrial Automation**, Exposure, 2007

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**PLASTICITY TECHNOLOGIES**
Professor/professors:	Saša S. Ranđelović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of plasticity technologies.

Course outcome

Students acquire knowledge that enables them to independently study and solve problems in plastic forming technologies, as well as plasticity theory as the basis for the design of industrial processes.

Course content

Theory classes

- Theoretical basis of the forming process
- Conditions of plasticity, analysis and application
- Mechanism of plastic deformation at the level of the grain structure, microforming
- Tensor calculus, mathematical plasticity theory
- Elements of continuum mechanics
- Modelling of forming processes
- Nonlinear FEM for quasi-stationary solid body forming processes
- FEM for small plastic deformations
- Planar stress state, analysis and FEM modelling
- Anisotropic plasticity, FEM modelling

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of plasticity technologies, state-of-the-art theoretical postulates that have been applied to industrial processes. Analysis of industrial problems using the finite element method and modelling of continuum flow in critical tool zones.

Recommended literature

1. Ranđelović S., Marinković S., **Proizvodne tehnologije [Production technologies]**, ISBN 978-86-6055-096-7 (COBISS.SR-ID 251312652), 356.str., Mašinski fakultet u Nišu, Niš, 2017.
2. Kojić M, **Computational procedures in inelastic analysis of solids and structures**, Univerzitet u Kragujevcu, Kragujevac, 1995.
3. Hosford W.F, Cadedell R.M., **Metal forming**, Mechanics and Metallurgy, CAMBRIDGE University press, ISBN-13 978-0-511-35453-3, 2007.
4. Marcinak Z., Duncan J.L., Hu S.J., **Mechanics of Sheet Metal Forming**, Butterworth Heinemann, ISBN 0 7506 5300 0, 2002.
5. EA de Souza Neto, Đ. Perić, DRJ Owen, **Computational methods for plasticity, theory and applications**, WILEY, ISBN 978-0-470-69452-7 , 2008
6. Stoiljković V., **Teorija obrade deformisanjem [Forming theory]**, Univerzitet u Nišu, 1982.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADVANCED CAPP/CAM SYSTEMS**
Professor/professors:	Miloš S. Stojković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	Passed exams at the PIT profile, UAS: Cutting Technology, Tools and Accessories, Planning of Technological Processes, NCMT Programming 1, Advanced Geometric Modelling, MAS: NCMT Programming 2

Course objective

Providing students with the highest level of knowledge of computer systems for designing technological machining processes so as to enable them to conduct future research and development in the above field.

Course outcome

After completing the course and passing the exam, students will be able to: design, simulate and analyse the most complex technological machining and control procedures using modern CAPP/CAM programming packages, generate an executive programming code for CNC machining and measurement and control machines (APT and G-code) as well as other output documentation (operation lists), apply the techniques of integrated numerical control of CNC systems, so-called DNC, with the aim of integrating complex manufacturing systems.

Course content

Theory classes

- Structure and trends in application of modern CAPP systems
- Advanced planning methods and reconfigurations of technological processes and routes using CAPP applications
- Advanced procedures in the design of technological CAM procedures
    - Machining of parts characterized by diverse topological elements
    - Grouped technological procedures (simultaneous machining by multiple tools)
    - Simultaneous machining of multiple parts (simultaneous machining of multiple parts by multiple tools)
- Advanced procedures in defining the tool path (CAM),
- Advanced procedures in analysis, simulation/verification and optimization of designed procedures
- Strong and weak formalization of knowledge and its use in
    - the categorization of the manufacturing procedure status (CAPP) and machining geometry (CAM),
    - the control of parts in the design of technological machining procedures (e.g. in CAM – selection of tools, accessories and modes, pre- and post-project instruction),
- Distributed numerical control of machining and measurement and control machines,
- Augmented reality in the domain of monitoring and control of technological machining and assembly processes,
- Current research areas in the field.

Guided independent research

- Independent work in modern CAPP/CAM and AR programming modules of the 3DExperience platform (Catia) and Creo in the examples from current research, or independent work in augmented reality systems in the examples from current research, should result in writing a term paper.
- Visits to modern manufacturing environments that apply CAPP/CAM systems intensively.

Recommended literature

1. M. Манић, Д. Спасић, **Нумерички управљане машине [Numerically controlled machines]**, Машински факултет, Ун. у Нишу, 1999.
2. T. C. Chang, R. A. Wysk, H.S. Wang**, Computer-Aided manufacturing**, 2. ed., 2006.
3. M. P. Groover, **Automation, Production Systems, and Computer-Integrated Manufacturing**, 2007
4. Selected scientific papers such as **Knowledge-Based CAD/CAPP/CAM Integration System for Manufacturing**, K. Wang, M. Tang, Y. Wang, L. Estensen, P.A. Sollie, M. Pourjavad**, Digital Enterprise Challenges**, IFIP — The International Federation for Information Processing Volume 77, 2002, pp 406-415

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures are held in a consultative manner and through interactive cooperation with the advisor and, optionally, appointed supervisor from a company. The course also includes visits by lecturers from companies that apply CAPP/CAM and AR systems intensively. Guided independent research is conducted under the instructions of the professor, advisor or, optionally, supervisor from a company on the topic selected from the field of the CAPP/CAM systems or augmented reality.

Knowledge assessment (maximum number of points 100)

Term paper (60) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADVANCED FEM ANALYSIS AND PRODUCT OPTIMIZATION**
Professor/professors:	Nikola D. Korunović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Providing students with a sufficient level of theoretical and practical knowledge related to:

- stress analysis of structures characterized by a pronounced nonlinear behaviour, subjected to complex mechanical and thermal loads or dynamic loads,
- structural and topological optimization of products from the aspect of durability, functionality and ability to be manufactured by various methods, including additive technologies,
- simulation of manufacturing processes for machine parts (forming, injection moulding and additive technologies).

Course outcome

Students are capable of independently applying the most important of the above knowledge and techniques in scientific research and industry.

Course content

Theory classes

- Application of the finite element method (FEM) in stress analysis of structures characterized by a pronounced nonlinear behaviour, both in product design and in simulation of manufacturing processes.
- Analysis of polymer and rubber products using FEM.
- FEM application in simulating heat transfer in an unsteady state. Direct coupled structural-thermal analysis.
- Dynamic analysis of structures using FEM. Dynamic analysis of structures subjected to harmonic excitations. Dynamic analysis of structures in transient modes.
- Structural optimization. Analysis of sensitivity and correlations between input and output parameters. Experiment planning. Response surfaces. Single- and multi-objective optimization.
- Topological optimization.
- Analysis of input model parameter robustness and prediction of failure probability in variations of structural variables.
- Simulation of the process of manufacturing parts using forming technologies.
- Simulation of the process of manufacturing parts using additive technologies.
- Simulation of mould filling by injection moulding.

Guided independent research

- Research in the given field, writing a term paper.
- Typical elements of scientific research related to analysis and simulation in biomechanics. Writing a paper for a scientific conference or a scientific journal.

Recommended literature

1. Selected chapters from Cook R.D., **Finite Element Modeling for Stress Analysis**, John Wiley and Sons, inc., 1995.,
2. NAFEMS, **Introduction to non-linear finite element analysis**, Glasgow, 2000, NAFEMS A Finite Element Dynamics Primer, Glasgow, 1992., Rothwell, A. (2017). Optimization Methods in Structural Design (Vol. 242). Springer.
3. Selected scientific papers.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Lectures are held in a consultative manner and through interactive cooperation with the advisor and, optionally, appointed supervisor from the industry. The advisor introduces students to the course content directly. After being introduced to the course content each student, in cooperation with the supervisor, chooses the topic of the project task and works on it. It is expected that the final result of working on the project task will be a manuscript, recommended for presentation at an international scientific conference.

Knowledge assessment (maximum number of points 100)

Term paper (60) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**NON-METALLIC MATERIALS**
Professor/professors:	Goran M. Radenković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective:

Acquiring new knowledge in the field of non-metallic materials: polymer materials, ceramic materials and composite materials.

Course outcome:

Students acquire knowledge that enables them to independently study and solve problems in the field of non-metallic materials.

Course content

Theory classes

- Polymer materials – thermoplastics, thermosets and elastomers
- Ceramic materials – tool ceramics based on nitrides and carbides, electrical insulation based on ceramics, fireproof ceramics and ceramics for coating metals and non-metals.
- Composite materials – polymer and ceramic matrices, glass, carbon, Kevlar and metallic fibres.

Guided independent research

- Preparing students to independently research scientific literature, professional journals and web portals in the field of polymer, ceramic and composite materials.

Recommended literature

1. Scientific papers available at KOBSON.

Number of active teaching classes	Lectures 4	Guided independent research 3

Teaching methods

Lectures and term paper.

Knowledge assessment (maximum number of points 100)

Term paper (60 points) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**KNOWLEDGE-BASED ENGINEERING SYSTEMS**
Professor/professors:	Milan B. Trifunović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Providing students with a necessary level of knowledge about knowledge-based engineering systems (KBES) in order to introduce them to the challenges and prepare them for future research in the field.

Course outcome

After the course is completed and the exam is passed, students will be able to:

- identify reasons and preconditions for KBES application, define goals for KBES application,
- design elements of KBES, simulate and test their performance,
- apply techniques for embedding KBES into modern CAx systems (CAD/CAE/CAPP/CAM systems), with the aim of improving performance and integrating complex production systems.

Course content

Theory classes

- Course introduction – origin and location of KBES application
- Knowledge representation models in engineering systems
  - Models of formalized knowledge
  - Models of non-formalized knowledge
  - Hybrid models of knowledge representation
- Models of computer-aided reasoning in engineering systems
  - Causal Reasoning
  - Model-Based Reasoning
  - Case-Based Reasoning
  - Analogy-Based Reasoning
  - Time context in the reasoning process
  - Hybrid models of reasoning
- Models and methods for embedding KBES into modern CAx systems
- Current research areas in the field

Guided independent research

- GIR – Analysis of needs for KBES application in real cases, selection of model and methods for its application. For the demonstration purposes and practical work students will use modules of the Catia, Siemens NX and Creo programming packages.
- Independent work: Writing a term paper – Analysis and guidelines for KBES application in the selected environment.

Recommended literature

1. Akerkar, R., Sajja, P., **Knowledge-Based Systems**, Jones and Bartlett Publishers, Sudbury, 2010
2. Sajja, P., Akerkar, R., **Advanced Knowledge-Based Systems: Models, Applications and Research**, TMRF e-Book, 2010
3. Milton, N.R., **Knowledge Technologies**, Polimetrica, Monza (Milan), 2008
4. Brachman, R.J., Levesque, H.J., **Knowledge representation and reasoning**, Elsevier, Amsterdam, 2004

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

A part of lectures is held in a conventional manner along with the consideration of real practice cases, while the other part of lectures is held in a consultative manner and through interactive cooperation with the advisor. Practice classes are held under the instructions and guidelines of the professor and advisor for GIR. The term paper is written independently, outside of practice classes.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**PRODUCT LIFECYCLE MANAGEMENT SYSTEMS**
Professor/professors:	Nikola M. Vitković, Saša S. Ranđelović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge and skills in the field of product development and lifecycle management.

Course outcome

Students are able to independently define the product development process, as well as technologies for its manufacturing. Furthermore, students are also able to independently develop a model of the process that allows for product lifecycle management. Students will be able to fully understand and apply different techniques and technologies, which are directly or indirectly involved in various aspects of product and service development.

Course content

Theory classes

- PLM (Product Lifecycle Management) systems – PLM elements (CAD, CAM, PDM, etc.); Process modelling by using certain standards (e.g. IDEF0, SADT); Modelling of systems and data floes by using UML; Strategies and modes of PLM subsystem implementation.
- System Engineering – Product systems, cycles and lifecycle; System architecture and data flow; System modelling by using appropriate techniques (Model-Based System Engineering); ERP (Enterprise Resource Planning) systems in PLM; Data acquisition on a product in all phases of its lifecycle, from conceptualization (including market research) to recycling/storing/removing.
- Knowledge Management – Information and knowledge; Semantic elements; Defining a tacit and explicit knowledge of a product; Knowledge representation.
- Product development – Research methods; Logistic systems; Product development methods (e.g. Waterfall, Agile); CAD/CAM methods involved in product development and manufacturing.
- Integrated PLM data, process and resource ecosystems in the context of an expanded enterprise (including its supply chain, i.e. value chain in which the selected product participates).
- Product traceability during its lifecycle. Traceability technologies: RFID, Smartdust.
- Product-as-a-service paradigm.
- Planned obsolescence paradigm.

Guided independent research

- Preparing students to independently research scientific and professional literature and other sources of information in the field of PLM. Developing certain subsystems during product development, as well as using modern techniques for product lifecycle management. Attending relevant online courses.

Recommended literature

1. Selected scientific papers and other scientific publications.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, demonstration of software tools, practical work with students on problem solving, term paper.

Knowledge assessment (maximum number of points 100)

Term paper with defence (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ENGINEERING ANALYSES OF BIOMEDICAL PRODUCTS**
Professor/professors:	Nikola D. Korunović, Miroslav D. Trajanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introduction to principles and techniques of using engineering analyses in the process of designing and manufacturing medical devices, implants and aids.

Course outcome

Students are familiar with various techniques for performing engineering analyses of medical devices, implants and aids, and are able to use them independently. Students are also able to work in research institutions or companies that provide scientific and technological support to medical institutions.

Course content

Theory classes

- Analysis and simulation in various branches of medicine:
  - Orthopaedics (endoprostheses, scaffolds and fixation elements)
  - Dentistry, orthodontology and cranio-maxillofacial medicine
  - Cardiology (stents and prostheses)
  - Gastrology (stents and prostheses)
  - Other branches
- Biomaterial modelling for engineering analyses
- Load modelling for engineering analyses. Principles of kinematic and dynamic analysis of walking
- Specificities of a model for analysis of medical devices, implants and aids using the finite element method
- Optimization of shapes and positions of implants, scaffolds, stents and prostheses
- Current development trends.

Guided independent research

- Research in the given field, writing a term paper
- Typical elements of a scientific paper related to analysis and simulation in biomechanics. Writing a paper for a scientific conference or a scientific journal.

Recommended literature

4. Moratal, D. (Ed.). (2012). **Finite Element Analysis: From Biomedical Applications to Industrial Developments**. BoD–Books on Demand.
5. Selected scientific papers.

Number of active teaching classes	Lectures	4	Guided independent research	3

Teaching methods

Classes are held in a consultative manner and through interactive cooperation with the advisor and, optionally, with the appointed supervisor – a researcher in the field of medicine or employed in the industry. The advisor introduces students to the course content directly. After being introduced to the course content, each student, in cooperation with the supervisor, chooses a topic for the project task and works on it. It is expected that the final result of the work on the project task is a manuscript, recommended for presentation at an international scientific conference.

Knowledge assessment (maximum number of points 100)

Term paper (60) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**COMPUTER SYSTEMS FOR ACQUISITION AND CONTROL**
Professor/professors:	Danijela D. Ristić-Durrant
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to various techniques of analysis and design of contemporary computer systems for acquisition and control for diverse classes of mechatronic objects.

Course outcome

Ability to define and design computer systems for acquisition and control for diverse classes of mechatronic objects.

Course content

Theory classes

- Application of computers in process industry, machine tools and communal systems control.
- Process visualization–SCADA.
- Activity detection and recognition.
- Acquisition and processing of measurement data.
- Application of PLC systems in process control.
- RTEthernetTCP/IP and Internet-based automation concept.
- Operator and touch panels.
- Problems of control of complex technological processes.
- Centralized control.
- Distributed control.
- Application of microprocessors in design and implementation of control systems.
- Hierarchical control.
- Choice of computer for real time control.
- Input-output devices.
- Software support for real time systems control.
- Computer coupling with technological processes.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web contents in the field of application of computer systems for acquisition and control in mechatronics, laboratory research.

Recommended literature:

1. Matijević M., Jakupović G., Car J., **Računarski podržano merenje i upravljanje [Computer-aided measurement and control]**, Mašinski fakultet u Kragujevcu, 2005.
2. Bailey D., Wright E., **Practical SCADA for Industry**, Elsevier, 2003.
3. M. SamiFadali, A. Visioli, **Digital Control Engineering: Analysis and Design**, Academic Press, 2012.
4. S. Sumathi, P. Surekha, **LabVIEW based Advanced Instrumentation Systems**, Springer, 2007.
5. K.Ogata, **Matlab for Control Engineers**, Prentice Hall, 2007.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**WIRELESS SENSOR NETWORKS**
Professor/professors:	Aleksandra M. Cvetković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Forming a knowledge base necessary for analysis, design and research in the field of wireless sensor networks

Course outcome

Understanding concepts of modern sensor networks and ability to conduct independent research in this field.

Course content

Theory classes

- Introduction to wireless sensor networks.
- Network architecture.
- Physical layer. Wireless channel and communication.
- Protocols. Working principles and design.
- Application of wireless sensor networks.
- Cooperation techniques in wireless sensor networks.
- Cooperation protocols in networks with simultaneous wireless transfer of information and energy.
- Processing and analysis of large amounts of data.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of wireless sensor networks.

Recommended literature

1. Karl, H., Willig, A., **Protocols and Architectures for Wireless Sensor Networks**, Wiley, 2007.
2. Dargie, W., Poellabauer C., **Fundamentals of Wireless Sensor Networks: Theory and Practice**, Wiley, 2010.
3. Selmic, R. R., Phoha, V. V., Serwadda, A., **Wireless Sensor Networks: Security, Coverage, and Localization**, Springer, 2016.
4. Kim D.-S., Tran-Dang H., **Industrial Sensors and Controls in Communication Networks: From Wired Technologies to Cloud Computing and the Internet of Things**, Springer, 2019.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, consultations, projects, scientific research.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Type and level of studies:	Doctoral Academic Studies
Study programme:	***Mechanical Engineering***
Course title:	**MEASUREMENT AND MONITORING OF TRANSPORT AND LOGISTIC SYSTEMS**
Professor/professors:	Danijel S. Marković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing doctoral students to experimental methods for measuring of transport machines and logistic systems. Building the conceptual knowledge of students about the objectives and categories of measurement. Customizing the subject matter to the needs of students for their future research work.

Course outcome

Mastery of knowledge of experimental studies of transport and logistic systems. Acquisition of one's own experience in experimental techniques and logistic applications. Ability to set up conceptual designs of measurement technical and logistic systems for certain classes of basic research. Knowledge of application software for experiments and monitoring. Writing papers and verification results through publication.

Course content

Theory classes

- Theory of measurement and measurement systems. Accuracy of measurements and standards.
- Monitoring of certain logistics systems in transportation engineering.
- Measurement and monitoring equipment.
- IT background of experimental research and monitoring.
- Analysis of several typical classes of measurement performed in the industry.
- Experiment in the example of stress, strain, displacement, force, velocity and vibration.
- Creating one's own measurement application and technical study on measurements.
- Experiment in scientific research.
- Systems for monitoring and control of means of transport. GPS/GPRS technologies, smart cards and RFID technology.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly related to the scientific model of the selected topic.

Recommended literature

1. John G. W.: **Measurement, Instrumentation, and Sensors Handbook**, CRC Press LLC, 2000.
2. Станковић Д.: **Физичко техничка мерења – мерење неелектричних величина електричним путем [Physical technical measurement – measuring non-electrical quantities electrically]**, Универзитет у Београду, Београд, 1991.
3. Hoffmann K.: **An Introduction to Measurements using Strain Gages**, HBM GmbH, Darmstadt, 1989.
4. HBM - Software Catman AP. 2012, HBM - Operating manual of device MGCplus, Darmstadt, 2004.
5. LabView, User manual, 2001.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Multimedia theoretical and experimental teaching. Laboratory work. Studies of derived measurement and logistic systems.

Knowledge assessment (maximum number of points 100)

Term paper or published scientific paper (50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MEASUREMENT AND EXPERIMENTAL RESEARCH IN HYDROPOWER ENGINEERING**
Professor/professors:	Živan T. Spasić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of measurement and experimental research. Enabling students to independently and on scientific principles define experimental research in hydropower engineering.

Course outcome

Students acquire knowledge that enables them to independently conduct measurements and experimental research in complex problems in hydropower engineering. They also acquire skills for independent work with measurement instruments, correct evaluation of measurement results and experimental determination of characteristics of hydropower machines and equipment.

Course content

Theory classes

- Electrical and technical measurements of macro flow parameters (pressure, velocity, flow rate),
- Electrical and technical measurements of turbulent characteristics,
- Measurement of angular velocity, torque and power,
- Processing and representation of measurement results, measurement errors and measurement uncertainty,
- Measurement instruments: working principles and characteristics,
- Measurement and experimental research of turbomachinery flow: experimental research of flow in rotational and stationary parts of turbomachinery, processing and representation of measurement results, calculation of turbomachinery characteristics by employing similarity theory,
- Measurement and experimental research in hydromechanical equipment,
- Measurement and experimental research in hydropower plants,
- Standards for measurement and experimental research in hydropower engineering.

Guided independent research

- Preparing students to do independent experimental research by writing a term paper on the topic directly correlated with the adequate model considered in the problem presented in the doctoral dissertation or as part of scientific research.

Recommended literature

1. Вушковић И., **Основи технике мерења [Basics of measurement techniques]**, Машински факултет Београд, 1976.
2. Bradshaw P., **An Introduction to Turbulence and its Measurement**, Pergamon Press, 1971.
3. Webster G. John, **Measurement, Instrumentation, and Sensors Handbook**, CRC Press LLC, 2000.
4. Upp E.L., Paul J. LaNasa, **Fluid Flow Measurement-A Practical Guide to Accurate Flow Measurement**, Butterworth.Heinemann, 2002.
5. Shao Lee Soo, **Instrumentation for fluid particle flow**, Noyes Publications, 1999.
6. Egon Krause, **Fluid Mechanics-With Problems and Solutions, and an Aerodynamic Laboratory**, Springer, 2005.
7. Повх И.Л., **Аеродинамический эксперимент в машиностроении,** Машиностроение, Москва-Ленинград, 1974.

Number of active teaching classes	Lectures 3	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (40 points). The requirement for taking the exam is the defended independently written term paper (60 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MEASUREMENT IN THERMAL ENGINEERING, THERMOENERGETICS AND PROCESS ENGINEERING**
Professor/professors:	Velimir P. Stefanović, Marko G. Ignjatović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to measurement systems, measurement instruments and methods for measuring parameters in fluid flow, at the macro and micro level, as well as to integral characteristics of fluid flow (heat and mass transfer...).
- Enabling students to formulate independently and on scientific principles appropriate experimental research in energy and process engineering, which is related to their doctoral dissertation.

Course outcome

- Acquired knowledge in the field of experimental research of fluid flow on the macro and micro levels.
- Acquired skills in the methodology of measurement and testing of characteristics of energy and process machines and equipment.

Course content

Theory classes

- Electrical and technical measurements of macro flow parameters,
- Electrical and technical measurements of turbulent characteristics,
- Measuring the composition of gases and liquids,
- Measurement of quantities that characterize the combustion process,
- Measurement in energy and process plants,
- Instrument characteristics,
- Operational modes of instruments,
- On-line and off-line measurement techniques,
- Static and dynamic characteristics of instruments,
- Measurement accuracy,
- Measurement standards.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate model considered in the problem presented in the doctoral dissertation.

Recommended literature

1. Eckert, Goldstein, **Measurements in Heat Transfer**, McGrow Hill-book-company, 1980.
2. Bradshaw P., **An Introduction to Turbulence and its Measurement**, Pergamon Press, 1971.
3. Webster G. John, **Measurement, Instrumentation, and Sensors** Handbook, CRC Press LLC, 2000.
4. Upp E.L., Paul J. LaNasa, **Fluid Flow Measurement-A Practical Guide to Accurate Flow Measurement**, Butterworth.Heinemann, 2001.
5. Shao Lee Soo, **Instrumentation for fluid particle flow**, Noyes Publications, 1999.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, consultations and guided independent research.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (40 points). The requirement for taking the exam is the defended independently written term paper (60 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ENGINEERING EXPERIMENT AND APPLICATION SOFTWARE IN MECHANICS**
Professor/professors:	Dragan B. Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to measuring systems, measuring instruments and methods of measurement.
- Enabling students to define scientific experimental research independently and based on scientific principles.
- Introducing students to the content and capabilities of basic software commonly used to solve problems in mechanics.

Course outcome

- Acquired knowledge in the theory of experimental research.
- Applying acquired knowledge in basic software to solving concrete engineering problems.

Course content

Theory classes

- Introduction to the technique of measuring devices. Introduction to measurement techniques.
- Characteristics of instruments. The experimental model.
- Accuracy and reliability of measurement. Standards of measurement.
- Optical methods in experimental mechanics.
- Measuring sensors. Transducers. Measuring amplifiers.
- Measurement systems with computational support.
- Measuring the length of the translational and angular displacements.
- Measurement of the time and frequency.
- Measurement of mechanical stress and force. Torque measurement.
- Measuring speed. Acceleration measurement.
- Measuring vibration and shock.
- Processing of experimental measurements on the computer (tables, graphs).
- Use of identifiers and commands. Data types. Variables. Expressions.
- Logical values and command selection. Loops and iterations. Numbered structures. Series and collections.
- Specialized mathematical software.
- Numerical differentiation and numerical integration.
- Numerical solution of differential equations.
- Solving systems of linear and nonlinear equations.
- Graphic presentation and problem solving.
- Certain applications in mechanics.

Guided independent research

- Selected experimental exercises in mechanics with the emphasis on the processing of measurement results and comparisons with other available results.
- Preparing students to conduct numerical research by writing a term paper directly correlated with the adequate mechanical model presented and considered in the doctoral dissertation.

Recommended literature

1. А. Грујовић, Н. Грујовић, **Техничка мерења II, III [Technical measurements II and III]**, Универзитет у Крагујевцу, Машински факултет у Крагујевцу, 2006.
2. В. Брчић, Р. Чукић, **Експерименталне методе у пројектовању конструкција [Experimental methods in the design of structures]**,“Грађевинска књига“, Београд,1988.
3. К. Сурла, Ђ. Херцег, **Математика и Mathematica [Mathematics and Mathematical]**, Природно-математички факултет Нови Сад, 1997.

Number of active teaching classes	Lectures 3	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**EXPERIMENTAL METHODS AND METROLOGY**
Professor/professors:	Milan S. Banić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to the concept of experiment, design of experiment, data acquisition, as well as the presentation of experimental results.
- Acquiring knowledge about measurement of mechanical quantities electrically, as well as gaining knowledge of signal processing for applications in control and information systems.
- Introducing students to measuring instruments, measuring systems and parameter measurement methods.
- Introducing students to the digital twin concept and its application in product lifecycle.

Course outcome

- Acquired knowledge in the theory of experimental research.
- Enabling students to individually and based on scientific principles define experimental research as part of their doctoral dissertation.
- Enabling students to define measuring points and apply measuring equipment.
- Acquired knowledge in the field of creating and applying digital twins.

Course content

Theory classes

- Fundamentals of measurement, the measuring chain.
- The principle of measuring nonelectrical quantities electrically. Advantages and disadvantages of electrical measurements of nonelectrical quantities.
- Transducers, operating principles and division.
- Resistive, inductive, capacitive, thermocouples, piezoelectric, photoelectric, radiation converters, and galvanic transducers.
- Processing and transmission of measurement signals. Analog and digital signal processing.
- Measurement of stress and strain state, force, torque, gas and fluid pressure.
- Measurement of temperature. Measurement of noise and vibration.
- Theory and experiment in engineering. Applied Statistics. Data acquisition.
- Design of experiment. Performing the experiment. Analysis and interpretation of experimental results.
- Digital twin concept. Types of digital twins. Creating a digital twin. Application of digital twins.

Guided independent research

- Preparing students to conduct independent experimental research as part of their doctoral dissertation.

Recommended literature

1. Стојиљковић В., **Мерење механичких величина електричним путем [Measurement of mechanical quantities electrically]**, Машински факултет Ниш, 2000.
2. Ранчић Б., **Системи за мерење, прикупљање и обраду података, I део [Systems for data measuring, acquisition and processing, part I]**, Машински факултет Ниш, 2005.
3. Миловančевић М: **Техничка дијагностика [Technical diagnostics]**, Машински факултет у Нишу, 2011.
4. Farsi M., Daneshkhah A., Hosseinian-Far A., Jahankhani H., **Digital Twin Technologies and Smart Cities**, Springer, 2019.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MEASUREMENT IN PRODUCTION SYSTEMS**
Professor/professors:	Predrag Lj. Janković, Miroslav R. Radovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The purpose of the course is to enable students to master the modern methodology of conducting measurements, analysis and processing of measurement results, and to become familiar with the measurement technique used for research into production systems and technologies.

Course outcome

After completing this course, students should be able to work independently with measuring instruments and properly evaluate the results of measurements. The knowledge that students gain in this course will enable them to successfully carry out experimental tests in their scientific research and work on doctoral dissertation.

Course content

Theory classes

- Measurement systems in production systems.
- Measuring equipment and measurements in certain production systems.
- Measurement uncertainty.
- Sensors and transducers.
- Computer-aided measurement systems.
- Technical and legal metrology.
- Processing of measured data.

Guided independent research

- Laboratory exercises (measurements of length and angle, deviation from the micro-shape, deviations from the macro-shape, inspection standards for length, and tolerance criteria).
- Visits to metrology laboratories and manufacturing facilities.

Recommended literature

1. Rančić B., **Sistemi za merenje, prikupljanje i obradu podataka, I deo [Systems for data measurement, acquisition, and processing, Part I]**, Mašinski fakultet, Niš, 2005
2. Hoffman K. **An Introduction to Measurements using Strain Gauges**, Hottinger Baldwin Messtechnik, Darmstadt, Germany, 1989
3. Pfeifer T. **Production Metrology**, Oldenbourg Verlag, Muenchen, 2002
4. Smith E. **Principles of Industrial Measurement for Control Applications,** Instrumentation Systems, 1984

Number of active teaching classes	Lectures 3	Guided independent research 3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Experimental work 70 points and oral exam 30 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**LABORATORY MATERIALS TESTING**
Professor/professors:	Goran M. Radenković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective:
Mastering the methodology of materials testing.

Course outcome:
Students acquire knowledge and skills for preparing and conducting materials testing.

Course content
- Mechanical materials testing
- Testing structure – optical, SEM, TEM
- Electrochemical testing
- Composite materials: polymer and ceramic matrices, glass, carbon, Kevlar and metallic fibres.

Guided independent research
- Preparing students to independently research, plan and conduct materials testing.

Recommended literature
1. Scientific papers available at KOBSON.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods
Laboratory work.

Knowledge assessment (maximum number of points 100)

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MATERIAL SELECTION**
Professor/professors:	Dušan Lj. Petković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective:
Acquiring new knowledge in the field of material selection.

Course outcome:
Students acquire knowledge that enables them to independently study and solve problems in the field of material selection.

Course content
- Connections between materials and product development
- Material selection as a specific process in product development
- Requirements and constraints in product development and properties of available materials
- Material selection as a decision-making process
- Material screening
- Multicriteria methods for material selection
- Decision-making support systems in material selection.

Guided independent research
- Preparing students to conduct independent research in the field of material selection.

Recommended literature

1. Kutz M.: **Handbook of Materials selection**, John Wiley & Sons,2002
2. Ashby M. F.: **Materials Selection in Mechanical Design, third edition**, Elsevier-Butterworth-Heinemann, 2005;
3. Петковић Д., **Избор биоматеријала - вишекритеријумска анализа и развој система за подршку одлучивању [Selection of biomaterials – multicriteria analysis and development of decision-making support systems]**, докторска дисертација, Машински факултет у Нишу, 2017
4. Filetin T., **Izbor materijala pri razvoju proizvoda [Material selection in product development]**, Sveučilišni udžbenik, FSB, Zagreb, 2006.
5. Jahan A. And Edwards K.L., **Multi-criteria Decision Analysis for Supporting the Selection of Engineering Materials in Product Design**, Elsevier, 2013.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods
Lectures, laboratory exercises and term paper.

Knowledge assessment (maximum number of points 100)
Term paper (60 points) and oral exam (40 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**STANDARDS, NORMS AND MEASUREMENT IN BIOMEDICAL ENGINEERING**
Professor/professors:	Jelena R. Milovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to legal norms and engineering standards relevant to the development and manufacturing of biomedical products. Furthermore, students are also introduced to appropriate measurement procedures, which are conducted in the development of biomedical products and for the purpose of their homologation.

Course outcome

Students are able to independently determine, for a chosen biomedical product, which measurements and testing need to be conducted for the purpose of achieving a regular process of the development of a biomedical product and assuring the compatibility of its properties with regulations and standards. Furthermore, students should be able to independently perform parts of such measurements and testing, those which can be performed in a laboratory.

Course content

Theory classes

- Recommendations and prospects for a global regulatory system for biomedical products
    - EC directive on biomedical products (MDD)
    - State of norms in the USA and Japan and a comparison with MDD
    - State of norms in other countries and a comparison with MDD
- ISO 13485 and 13488 standards and guidelines for quality systems in the design and manufacturing of medical products
- Standards and guidelines for biocompatibility of biomedical products
- Role of standards in the quality assessment of biomedical products
- Influence of biomaterials in the sense of safety and efficiency of medical devices and implants
- Nonclinical testing of medical devices
- Failure analysis
- Mechanical testing of implants
    - Cranio-maxillofacial implants
    - Implants for spine trauma and fracture fixation
    - Orthopaedic implants for upper and lower extremities
- Current research areas in the field

Guided independent research

- Independent research into the relevant norms for the development of the selected BM product
- Definition of the procedure/matrix for the quality assessment of the selected BM product
- Preparation and performance of a test/measurement relevant for the selected dissertation topic in the field of SNM BME
- Writing a term paper (report on the performed test) that should be transformed into a scientific paper for a scientific conference or a scientific journal

Recommended literature

1. Gordon R Higson, 2002. **Medical Device Safety *The Regulation of Medical Devices for Public Health and Safety,*** IOP Publishing Ltd 2002
2. Michael N. Helmus, 2002. **Biomaterials in the Design and Reliability of Medical Devices**, Tissue Engineering Intelligence Unit, 2002 Eurekah.com Landes Bioscience
3. **Mechanical Testing of Orthopaedic Implants**, 2017. (Ed.) Elizabeth Friis, Woodhead Publishing Series in Biomaterials, Elsevier
4. **Regulatory Affairs for Biomaterials and Medical Devices**, 2014. (Eds.) Stephen F. Amato, Robert M. Ezzell, Jr -Woodhead Publishing
5. **Standards, Quality Control, and Measurement Sciences in 3D Printing and Additive Manufacturing, 2017,** Chee Kai Chua, Chee How Wong and Wai Yee Yeong (Auth.), Academic Press.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures are held in a consultative manner and through cooperation with the advisor. Students, in cooperation with the advisor and the course professor, choose the topic of the term paper and work on it. The final result should be a manuscript, recommended for presentation at a scientific conference or publication in a scientific journal.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**STOCHASTIC SYSTEMS**
Professor/professors:	Vlastimir D. Nikolić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to different analysis and design techniques of modern stochastic control systems for various classes of mechatronic objects.

Course outcome

Enabling students to analyse and design scalar, multivariable, continuous and discrete linear stochastic systems, as well as nonlinear stochastic systems with constant and variable structure.

Course content

Theory classes

- Random variables.
- Stochastic processes.
- Polynomial form of models of scalar continuous and discrete stochastic systems.
- Polynomial form of models of multivariable continuous and discrete stochastic systems.
- Analysis of continuous and discrete linear stochastic systems.
- Design of scalar continuous and discrete linear stochastic systems.
- Design of multivariable continuous and discrete linear stochastic systems.
- Analysis and design of linear stochastic systems with delay.
- Optimal control of stochastic systems with delay.
- Optimal control of nonlinear stochastic systems with constant and variable structure.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web contents in the field of stochastic control systems in mechatronics.

Recommended literature:

1. D. Debeljković, **Stohastički linearni sistemi automatskog upravljanja [Stochastic linear systems of automatic control]**, Naučna knjiga, Beograd, 1985
2. T. Soderstrom, **Discrete – time stochastic systems, Estimation and Control**, Prentice Hall, London, 1994.
3. J – Q. Sun, **Stochastic Dynamics and Control**, Elsevier, London, 2006.
4. F. L. Lewis, V. L. Szrmos, **Optimal Control**, John Willey & Sons, Inc., New York, 1995.
5. R. F. Stengel, **Optimal Control and Estimation**, Dover Publications, Inc. New York, 1994.
6. A. Bagchi, **Optimal Control of Stochastic Systems**, Prentice Hall, London, 1993.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**INTELLIGENT CONTROL AND ROBOTIC SYSTEMS**
Professor/professors:	Žarko M. Ćojbašić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to advanced techniques of analysis and design of contemporary intelligent control systems for diverse classes of mechatronic objects and modern robotic systems.

Course outcome

The course outcome is the ability of students to study, analyse and design a new generation of intelligent control systems for diverse modern mechatronic and robotic systems.

Course content

Theory classes

- Concept of intelligent systems and their characteristics.
- Soft computing and computational intelligence.
- Artificial intelligence and machine learning.
- Conventional techniques of computational intelligence.
- Integration of various soft computing techniques in hybrid systems.
- Advanced techniques of computational intelligence.
- Deep machine learning.
- Convolutional neural networks.
- Recurrent networks.
- Intelligence in mechatronics – control task.
- Intelligent control systems in mechatronics.
- Neuro-fuzzy-genetic models and control systems.
- Robotics and artificial intelligence.
- Cognitive robotics.
- New generation industrial robots.
- Intelligent behaviour of industrial and mobile robots in the interaction with the technological environment in Industry 4.0.
- Advanced software tools for modelling and analysis of intelligent mechatronic and robotic systems.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web contents in the field of intelligent control systems in mechatronics and robotics. Laboratory and experimental research.

Recommended literature

1. Maki K. Habib, (2019), **Handbook of Research on Advanced Mechatronic Systems and Intelligent Robotics**, IGI Global.
2. Marcin Szuster, Zenon Hendzel (2018**), Intelligent Optimal Adaptive Control for Mechatronic Systems**, Springer.
3. Jinkun Liu (2017**), Intelligent Control Design and MATLAB Simulation**, Springer.
4. Thomas R. Kurfess (2018), **Robotics and Automation Handbook**, CRC Press.
5. Hooman Samani (2015), **Cognitive Robotics**, CRC Press.
6. Весна Ранковић (2008), **Интелигентно управљање [Intelligent control]**, Машински факултет у Крагујевцу, Крагујевац.
7. Pedro Ponce Cruz, Fernando D. Ramírez-Figueroa (2009), **Intelligent Control Systems with LabVIEW**, Springer.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper, guided independent theoretical and experimental research.

Knowledge assessment (maximum number of points 100)

The exam is taken in the form of the oral defence (30 points) of the independently written term paper (70 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**REHABILITATION ROBOTICS**
Professor/professors:	Danijela D. Ristić-Durrant
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to one of the most recent and challenging fields of robotics, rehabilitation robotics. At first, historical development and application of robotics in rehabilitation are discussed followed with an overview of modern trends in rehabilitation robotics, which make this field a multidisciplinary one, including fields such as robotics, automatic control, cognitive science and neurorehabilitation. The course objective is to gain knowledge about the principles of development of different robotic rehabilitation systems, as representatives of robotic systems that interact directly with humans.

Course outcome

Enabling students to develop concepts of robotic systems that interact physically with humans during the rehabilitation of upper and/or lower extremities.

Course content

Theory classes

- Chronological overview of development and application of robots in rehabilitation.
- Modern trends in rehabilitation robotics.
- Robotic systems for rehabilitation of upper human extremities.
- Robotic systems for gait rehabilitation.
- “Human-centred“ approach in the design of robotic rehabilitation systems.
- Sensors in rehabilitation robotics.
- Control methods in rehabilitation robotics.
- Cognitive robotic rehabilitation systems.
- Evaluation of robotic systems for rehabilitation.

Guided independent research

- Preparing students to independently research scientific journals and web contents in the field of rehabilitation robotics. Preparing students to develop a concept of a robotic system for application in rehabilitation.

Recommended literature:

1. B. Siciliano, O. Khatib, (Eds.), **Springer Handbook of Robotics,** Springer, 2008.
2. S. S. Kommu (Ed.), **Rehabilitation Robotics**, I-Tech, 2007 (open access book).

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**OPTICAL SYSTEM DESIGN**
Professor/professors:	Nenad T. Pavlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of functional optical elements, optical instruments, and techniques of computer-aided optical system design.

Course outcome

The ability to calculate and design optical systems as constituent parts of complex mechatronic systems.

Course content

Theory classes

Prisms and mirrors

- Reflective prisms;
- Dispersive prisms;
- Plane mirrors. Plane mirrors in the shape of a plate;
- Design of prism systems and reflector systems;
- Analysis of manufacturing errors.

Basic optical instruments and devices

- Afocal systems. Telescopes;
- Simple microscope. Magnifying glass;
- Compound microscope;
- Photometric devices;
- Radiometric and detection devices;
- Fibre optic devices.

Optical systems

- Camera lenses;
- Achromatic telescope objectives;
- Cooke triplet anastigmats;
- Techniques of optical system design without computers;
- Techniques of computer-aided optical system design;
- Telescopic systems and oculars;
- Microscopic objectives;
- Photographic objectives;
- Condenser systems;
- Reflector systems.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of optical system design.
- Use of programming packages for optical system design (ZEMAX, PARAX).

Recommended literature:

1. Haferkron, H., Pavlović,N., **Tehnička optika [Optical engineering]**, Mašinski fakultet Niš, Niš, 1989.
2. Smith, W.J., **Modern Optical Engineering**, McGraw-Hill, 2000.
3. Fischer, R.E., **Optical System Design**, McGraw-Hill, 2000.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MICRO- AND NANOELECTROMECHANICAL SYSTEMS**
Professor/professors:	Jelena Ž. Manojlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Miniaturization techniques play an important role in engineering today (mechanical engineering, electronic engineering, materials...). This course introduces students to micro- and nanotechnologies, materials, physical effects and phenomena characteristic for the micro- and nanoenvironment. Students acquire a theoretical basis, an insight into the necessity of application of micro- and nanosystems in different areas and learn of possibilities of further development of micro- and nanoengineering.

Course outcome

Students are trained to understand the phenomena in the micro- and nanoworld (typical physical phenomena such as friction, adhesion, wear, lubrication, etc.), and in turn gain a deeper understanding of the causes for the occurrence of such phenomena. Acquired knowledge is further applied in designing micro- and nanoelements and systems.

Course content

Theory classes

- Physical basis of micro-and nanomechanics (material properties, physical effects, principles and phenomena in the microworld).
- Study of phenomenon of friction, adhesion, wear and lubrication at the molecular level.
- Examination of chemical, physical and mechanical properties of surfaces.
- Instruments for studying the phenomena at the micro- and nanolevel.
- Technologies of micromechanics and nanotechnology.
- Small dimensions devices, micro- and nanoelectromechanical systems (MEMS and NEMS).
- Directions of further development of micro- and nanotechnology.
- Analysis of physical effects, principles and phenomena in implemented micro- and nanoelectromechanical systems.
- Modelling and simulation of functional principles of micro- and nanosystems.
- Application of technologies of micromechanics and nanotechnology for designing micro- and nanoelements and systems.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of micro- and nanoelectromechanical systems.

Recommended literature:

1. Madou J. M., **Fundamentals of Microfabrication: The Science of Miniaturization**, CRC Press, 2002.
2. Lyshevski E. S., **Nano- and Micro-Electromechanical Systems: Fundamentals of Nano- and Microengineering**, Taylor & Francis, 2005.
3. Pelesko A. J., Bernstein H. D., **Modeling MEMS and NEMS**, CRC Press; 2002.
4. Jeremy Ramsden, **Nanotechnology-An introduction**, William Andrew, Year: 2016, ISBN: 032339311X
5. Lyshevski E. C., **Nano- and Microscience, Engineering**, Technology, and Medicine Series, CRC Press LLC, N.W., 2000., ISBN 0-8493-1262-0.
6. Kottapalli A.G.P., Sengupta K.T.D., Triantafyllou M.S., **Self-Powered and Soft Polymer MEMS/NEMS Devices**, Springer, 2019., ISBN 978-3-030-05553-0

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 25 points = 50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS**
Professor/professors:	Goran S. Petrović, Žarko M. Ćojbašić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course objective is to broaden knowledge in transport systems from the aspect of intelligent control, which is essential to students for further scientific research.

Course outcome

Improving the general level of education in the field of transport systems. The fundamental outcome is students' capability to conduct research, as well as analyse and develop a new generation of intelligent control for transport systems.

Course content

Theory classes

- Cooperative, intelligent and automated mobility – open problems, tasks and prospects.
- Intelligent systems and their advanced characteristics.
- Computational intelligence, artificial intelligence and machine learning, and advanced application in modern intelligent transport systems. Integration of diverse techniques of computational intelligence in hybrid systems. Artificial neural networks, recurrent networks, convolutional networks.
- Fuzzy systems. Metaheuristic optimization.
- Machine learning and deep machine learning.
- Advanced intelligence in transport engineering and logistics – a complex control task based on the innovative application of computational intelligence and machine learning.
- Application of wireless communications of the new generation and the Internet of Things technologies in cooperative intelligent transport systems. Communication security and data protection.
- Cooperative intelligent transport systems in urban areas and specific problems (automated transport and traffic monitoring, passenger information, freight and fleet management...).
- Systems for tracking the movement of intelligent means of transport, the problem of simultaneous localization and mapping in dynamic environments.
- Intelligent and automated guided vehicles (AVG) and application of robotic technologies in intelligent transport systems of the new generation.

Guided independent research

- Preparing students to research written literature, scientific journals and web contents in the field of cooperative intelligent control systems in transport engineering and logistics. Laboratory and experimental research.

Recommended literature

1. Ghosh, S. and Lee. T.S.: **Intelligent Transportation Systems: Smart and Green Infrastructure Design**, Second Edition, Taylor & Francis, 2010.
2. EUROPEAN COMMISSION: **A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility**, COM(2016) 766 final
3. Sussman, J.M.: **Perspectives on Intelligent Transportation Systems (ITS)**, Springer, 2008.
4. Hong, C.: **Autonomous Intelligent Vehicles, Theory, Algorithms, and Implementation**, Springer, 2011.
5. Ранковић В.: **Интелигентно управљање [Intelligent control]**, Машински факултет у Крагујевцу, Крагујевац, 2008.
6. Cruz P.P., Ramírez-Figueroa, F.D.: **Intelligent Control Systems with LabVIEW™**, Springer, 2009.
7. Петровић, Г., и други: **Одрживи, интелигентни и еколошки транспорт и логистика у урбаном контексту - практикум модула SIETLU [Sustainable, intelligent and environmental transport and logistics in the urban context – practicum of the SIETLU module]**, Универзитет у Нишу Машински факултет, 2019.
8. Lu, M.: **Cooperative Intelligent Transport Systems: Towards high-level automated driving**, Institution of Engineering and Technology, Stevenage, United Kingdom, 2019.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper.

Knowledge assessment (maximum number of points 100)

The exam is taken by orally defending (30 points) the independently written term paper (70 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**DYNAMICS OF MOBILE MACHINES**
Professor/professors:	Vesna D. Jovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of modelling and development of dynamic mathematical model functions, kinematic chains, transmissions and drive mechanisms of mobile (construction, transport, mining, agricultural and communal) machines.

Course outcome

The ability to study and analyse the dynamics of mobile machines in their development, design and testing.

Course content

Theory classes

- Fundamentals of terramechanics – characteristics of land as the subject of work and support of mobile machines. Dynamic modelling of relations between the subject of work and tools of mobile machines. Dynamics of motion of mobile machine tracked mechanisms. Dynamics of motion of mobile machines with tires.
- Procedures of inverse and direct dynamics of kinematic chains. Dynamic modelling of kinematic chains of mobile machines with rigid chain members. Dynamic modelling of kinematic chains of mobile machines with flexible chain members. Dynamic simulation of kinematic chains of mobile machines.
- Dynamics of hydrodynamic motion transmissions in mobile machines. Dynamics of hydrostatic motion transmissions in mobile machines. Dynamic simulation of motion transmissions in mobile machines.
- Dynamic analysis of drive mechanisms with hydraulic cylinders as actuators. Dynamic analysis of drive mechanisms with hydraulic motors as actuators. Dynamic simulation of drive mechanisms in mobile machines.
- Mathematical models for determining the dynamic stability of mobile machines. Dynamic stability testing of mobile machines. Defining the dynamic criteria for assessing the stability of mobile machines.

Guided independent research

- Solving numerical tasks.

Recommended literature

1. Јаношевић Д., Јовановић В.: **Синтеза погонских механизама хидрауличких багера [Synthesis of drive mechanisms in hydraulic excavators]**, Машински факултет Универзитета у Нишу, Ниш, 2015.
2. Јаношевић Д.: **Пројектовање мобилних машина [Design of mobile machines]**, Машински факултет у Нишу, Ниш, 2018.
3. Kunce G., Gohring H., Jacob K.: **Baumaschinen**, Vieweg & Sohn Verlagsgesellschaft mbH, Braunschweig/ Wiesbaden, 2002.
4. Vinogradov O.: **Fundamentals of kinematics and dynamic of machines and mechanisms**, CRC Press Boca Raton, London, New York, Washington, D.C., 2000.
5. Dresig H., Holzweißig F.: **Dynamics of Machinery Theory and Applications**, Springer, 2010.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, consultations and independent research on the study into the dynamics of mobile machines.

Knowledge assessment (maximum number of points 100)

The exam is taken by orally defending (30 points) the independently written term paper (70 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MANAGEMENT IN TRANSPORT**
Professor/professors:	Nikola S. Petrović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of management in transport, introduction to and acquisition of modern methods and techniques, enabling students to apply the knowledge from this field.

Course outcome

Students acquire knowledge that enables them to independently study and solve problems of management, organization, decision-making and efficiency in transport with the application of modern methods and techniques.

Course content

Theory classes

- Management in transport. Management by objectives and results. Management as a key resource in the 21st century.
- Transport production and industrial structure analysis. Transport demand. Transport costs. External transport effects. Imperfect competition in transport markets. Transport infrastructure and investments. Supply organization. Transport market characteristics and state intervention.
- Decision-making. Strategic and operational decision-making. Decision-making process. Optimal decision-making in the transport sector. Forms and effects of competition between operators. Transport infrastructure and the problem of optimal efficiency.
- Business decision-making, concepts and methodologies. Parameters and indicators of fleet operation.
- Parameters and indicators of temporal fleet efficiency. Efficiency of travelled distance and vehicle capacity. Vehicle productivity and fleet operation.
- Measuring transport efficiency by data envelopment analysis (DEA method). Basic DEA models. DEA models with weight restrictions. Modifications of DEA models in line with the status of variables. DEA models for ranking.
- Transport infrastructure and regional development. Special cases – urban transport, transport in transition countries, new economics of sustainable transport.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of management, organization, decision-making and efficiency in transport.

Recommended literature

1. Hwang C.L., Yoon K.P.: **Multiple Attribute Decision Making**, Springer-Verlang, 1981.
2. Teodorovic D., Janic M.: **Transportation Engineering: Theory, Practice and Modeling**, Oxford: Butterworth-Heinemann, Elsevier, 2017.
3. Vuchic R. V.: **Urban Transit Systems and Technology**, John Wiley & Sons, 2007.
4. Jean-Paul R., Comtois C., Slack B.: **The Geography of Transport Systems**, Third edition,Routledge, 2013.
5. Aist W., Hee K.: **Workflow Management: models, methods, and systems**, MIT Press, 2002.
6. Forman, H, E. Selly, M.A.: **Decision by Objectives**, World Scientific Publishing Company, London, 2001.
7. Journals: Journal of Management, Review of Managerial Science, Journal of International Management, Management Science, Omega.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN INTERNAL COMBUSTION ENGINES AND HYBRID SYSTEMS**
Professor/professors:	Boban D. Nikolić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge of the causal relations between work cycle parameters and operating characteristics of internal combustion engines (ICE), selected auxiliary ICE systems and hybrid systems.

Course outcome

Enabling students to conduct professional and scientific research in the field of ICE and hybrid systems. Students acquire knowledge that enables them to independently study and solve problems in working substance distribution processes, engine cooling, ICE fuel feeding systems and exhaust gas emissions, as well as to identify hybrid vehicle drives and their components, explain the manner of functioning, analyse operation control algorithms and operation modes of hybrid systems, and analyse energy and environmental performance in concrete examples.

Course content

Theory classes

- Introductory considerations. Multicriteria analysis of ideal and real thermodynamic cycles in modern IC engines. Relations between input parameters of working fluids and external speed characteristics of engines.
- Working substance distribution systems. Specificities of IC engines with fuel feeding. Calculation and determination of distribution system parameters. Process and system modelling.
- ICE cooling systems. Calculation and selection of system components. Compatibility of existing systems for engine cooling with drive systems of alternative fuel engines.
- ICE fuel feeding systems. Parameter calculation. Alternative fuel characteristics – determining the characteristics based on their influence on the operation of fuel feeding systems, fuel spray formation, mixtures and combustion, and their optimization. Modelling and optimization of system operation.
- ICE exhaust gas emission. Emission control and emission reduction systems. Optimization possibilities and modern solutions for separate and integrated systems for emission reduction.
- Hybrid drives and technical specifications. Types, divisions, constituent systems, components and pictogram.
- Operation modes of hybrid systems, energy flow and regeneration.
- Studying different solutions of hybrid systems and examples of hybrid and electric vehicles.
- Battery units in hybrid vehicles. Types, components, cooling, maintenance and safety.
- Environmental and energy challenges.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of ICE and hybrid systems, by writing a term paper that deals with the problems that are in line with the tasks set out in the doctoral dissertation.

Recommended literature

1. Дорић Ј.: **Теорија Мотора СУС [Theory of internal combustion engines]**, Факултет техничких наука, Нови Сад, 2015.
2. Hillier, V.A.W.: **Hillier’s Fundamentals of Motor Vehicle Technology**, 6th Edition, Book I, Oxford University Press, UK, 2014.
3. Cornel S.: **Alternative Propulsion for Automobiles**, Springer, 2017.
4. Благојевић И., Митић С.: **Возила и животна средина [Vehicles and the environment]**, Машински факултет Београд, 2017.
5. Nikolić B.: **Istraživanje karakteristika ubrizgavanja ulja repice i njegovog metil estra pod visokim pritiscima u motorima SUS [A study into the characteristics of injecting rapeseed oil and its methyl ester under high pressure in internal combustion engines]**, Doktorska disertacija, Univerzitet u Nišu, Mašinski fakultet u Nišu, Niš, 2016.
6. Journals: International Journal of Engineering Science, International Journal of Automotive Technology, Fuel, Energy and Fuels, Biotechnology for Biofuels, Thermal Science, etc.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper.

Knowledge assessment (maximum number of points 100)

Term paper (50 points) and oral exam (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**ADVANCED COURSE IN AUTOMOTIVE ENGINEERING**
Professor/professors:	Dragan A. Ružić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to the theoretical background of processes and phenomena in motor vehicle technology.
- Enabling students to independently, objectively, systematically and critically study and solve problems in the field of automotive engineering, based on scientific principles, and for the purpose of writing scientific papers and doctoral dissertation.

Course outcome

Students acquire necessary scientific knowledge in selected scientific disciplines implemented in the field of motor vehicles, applicable to their scientific research in the area of automotive engineering.

Course content

Theory classes

- Chassis and bodies. Structural requirements: loading, vibration, safety, integration. Modelling using modern computer tools.
- Drive system. Contemporary and future technologies of motor vehicle drives. Environmental aspect of vehicle exploitation. Modelling and simulation of processes in the drive system using modern computer tools.
- Vehicle dynamics. Surface and tire interaction. Vertical, lateral and transversal dynamics. Modelling of dynamic systems in motor vehicles.
- Thermal processes in vehicles. Thermal processes in drive systems. Thermal interaction between a human and a vehicle cab. Simulation of thermal processes using modern computer tools.
- External aerodynamics. Theory of aerodynamic processes in motor vehicles. Simulation of aerodynamic processes using modern computer tools.
- Automobile safety and testing of road vehicles.

Guided independent research

- Preparing students to do research within their doctoral dissertation, by writing a term paper that deals with the problems from the selected field of automotive engineering, and in line with the problem presented in the doctoral dissertation.

Recommended literature

1. Malen D.: **Fundamentals of Automobile Body Structure Design**, SAE International, 2011.
2. Јанковић А., Симић Д.: **Безбедност аутомобила [Automobile safety]**, DSP - Mecatronic, Крагујевац, 1996.
3. Bhise V.: **Ergonomics in the automotive design process**, Taylor & Francis Group, 2012.
4. Meywerk, M.: **Vehicle Dynamics**, Chichester, West Sussex, Wiley, 2015.
5. Rill G.: **Road Vehicle Dynamics**, Boca Raton, CRC Press, 2012.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term paper based on the selection and analysis of contemporary literature sources, application of experimental research and/or numerical modelling and problem analysis procedures.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**FLUID BIOMECHANICS**
Professor/professors:	Miloš M. Kocić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Application of knowledge of fluid mechanics in the modelling of biological systems. The development of multidisciplinary research with medical sciences, where the principles of fluid mechanics are very important in the study of the origin and development of certain diseases.

Course outcome

Adopted contemporary knowledge necessary for the study of mathematical and numerical methods used in the modelling of the blood flow in the cardiovascular system and the flow of air in the respiratory system.

Course content

Theory classes

- Multi-phase flow, non-Newtonian elastic model, pseudo-plastic fluids, dilatant fluids, Bingham fluids.
- Linear viscoelastic models. Nonlinear viscoelastic models.
- Blood composition, rheology properties, constitutive modelling of blood, inelastic models.
- Heart, anatomy and flow domain, operating principles of heart “valves”, pumping mechanism, systole, diastole.
- Unsteady pulse flow: Womersley solution, Womersley solution and Stokes layer.
- Small Womersley number limit, flow rate at unsteady flow, application to real physiology conditions.
- Turbulent flow, the friction coefficient.
- Hemodynamic flow current, curved vessels, secondary flow, flow separation and recirculation, wall shear stresses, oscillatory shear index.
- Formation and development of atherosclerosis, the role of hemodynamics, lipid accumulation and changes in the flow pattern.
- Arteries, Windkessel model, oscillatory inflow model, elastic waves, arterial distension and waveform, Korteweg-Moens wave speed.
- Microvasculature, two-phase model of blood flow in the capillaries.
- Fahraeus-Lindqvist effect, distribution of haematocrit.
- Fahraeus effect, pressure distribution in micro vessels, blood flow in individual micro vessels, micro vascular bifurcations.
- Autoregulation of blood flow, vasoconstriction and vasodilatation.
- Air circulation and the respiratory system.
- Mechanism of breathing. Mass transfer and diffusion. Particle transport in the lungs.
- Numerical methods for complex fluids.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a paper on the topic directly correlated with the adequate model considered in the problem presented in the doctoral dissertation.

Recommended literature

1. C. Ross Ethier, C.A. Simmons, **Introductory Biomechanics**, Cambridge University Press (2007).
2. C. Kleinstreuer, **Biofluid Dynamics**, Taylor and Francis Press (2006).
3. Y.C. Fung, **Biomechanics: circulation**, Springer (1996).

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, creation of mathematical models, experimental exercises, term paper.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF FLOW THROUGH POROUS MEDIA**
Professor/professors:	Jelena D. Petrović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing doctoral students to the theory of flow through porous media and enabling them to independently define and model problems in this field.

Course outcome

Acquired necessary knowledge for studying mathematical and numerical methods used in modelling fluid flow through porous media.

Course content:

Theory classes

- Basic concepts. Porous media.
- Darcy's law. Permeability of porous media.
- General hydrodynamic equations for fluid flow through porous media.
- Equations of motion, initial and boundary conditions. General form of Darcy's law.
- General characteristics and modelling of porous media.
- Fluid flow through porous media. Heat transfer in porous media.
- Two-dimensional flow problems.
- Three-dimensional flow problems.
- Gravitational flow systems.
- Nonuniform permeability systems.
- Two-fluid flow.
- Incompressible fluid flow through porous media.
- Gas flow through porous media.
- Fluid flow through porous media under the influence of a magnetic field.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate model considered in the problem presented in the doctoral dissertation.

Recommended literature

1. D. B. Ingham, I. Pop **Transport phenomena in porous media**, Elsevier (2005).
2. Kambiz Vafai, **Handbook of porous media**, Taylor and Francis Press (2005).
3. Donald A. Nield, Adrian Bejan, **Convection in porous media**, Springer (2006).

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, creation of mathematical models, experimental exercises, term paper.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**NUMERICAL SIMULATION OF FLOW IN TURBOMACHINERY**
Professor/professors:	Živan T. Spasić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to the course content on the methodology of numerical simulations of fluid flow in turbomachinery.
- Enabling students to work independently with appropriate software.

Course outcome

- Acquired knowledge of the methodology of numerical simulations of fluid flow in turbomachinery.
- Acquired skills in operating appropriate software and using the methodology of numerical simulations.

Course content

Theory classes

Theoretical basics of numerical simulations

- Basic equations of fluid flow in turbomachinery.
- Finite volume method.

Software for numerical simulations of fluid flow in turbomachinery

- Formulation of a physical model.
- Generation of flow domain of axial and radial turbomachinery.
- CAD software and ICEM CFD software for generating models of flow domain.
- Models of rotational and stationary elements of turbomachinery.

Numerical simulation of flow in turbomachinery

- Generation of numerical mesh, types of control volumes, density criterion and independence of numerical solution and numerical mesh.
- Defining physical values, boundary values, numerical parameters, format of output data, rotational and stationary part of flow domain.
- Functional processor elements (choice of flow model, solver, monitoring of convergence, convergence criterion).
- Steady and unsteady flow simulations, initial values, boundary values, time step, process dynamics, selection of appropriate models.
- Graphical postprocessing of numerical results (static and turbo mode).
- Representation of results using figures and diagrams. Creating animations based on obtained numerical results.

Complex problems of numerical simulation of flow in turbomachinery

- Changing the flow domain, moving elements, changing the mesh.
- Numerical simulation of unsteady flow processes, stall, cavitation.
- Models of two-phase flows in simulation of cavitation in turbomachinery.

Accuracy of numerical simulation

- Optimal choice of model. Choice of solver, discretization schemes and algorithms.
- Defining additional values. Determination of mesh influence on the numerical solution.
- Problems of numerical solution convergence. Possibilities of solving problems.

Advantages and disadvantages of numerical simulation. Research costs.

Guided independent research

- Preparing students to work in appropriate software as part of their doctoral dissertation by writing two term papers on the topics directly correlated with the problem presented in the doctoral dissertation.

Recommended literature

1. Joel H. Ferziger, Milovan Peric, **Computational Methods for Fluid Dynamics**, Springer, 2002.
2. John D. Anderson, **Computational Fluid Dynamics: The Basics with Applications**, McGraw Hill, 1995.
3. B.P.M. Van Esch, **Simulation of three-dimensional unsteady flow in hydraulic pumps**, Febodruk BV, 1997.
4. H K Versteeg and W Malalasekera**, An Introduction to Computational Fluid Dynamics,** Edinburgh Gate, 2007.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (40 points). The requirement for taking the exam is the defended independently written term paper (60 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MODEL AND EXPERIMENTAL RESEARCH INTO HYDRAULIC MACHINES AND FANS**
Professor/professors:	Saša M. Milanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the course content on model and experimental research into hydraulic machines and fans. Enabling students to independently and on scientific principles formulate appropriate model and experimental research, as part of their doctoral dissertation.

Course outcome

Students acquire knowledge of the theory of creating models and prototypes and skills in the methodology of measuring and testing characteristics of hydraulic machines and fans.

Course content:

Theory classes

Tasks of model and experimental research.
- Measurements of model operating characteristics and recalculation for the main (improved) design. Changing the blade shape and other boundary surfaces in order to obtain better operating characteristics of the turbomachinery.
- Experimental research into flow in turbomachinery elements and profile cascades, as a source of information for the improvement of existing calculation procedures.

Laws of flow similarity.
- Similarity coefficients.
- Dimensionless operating characteristics of hydraulic turbomachinery and fans.
- Influence of Reynolds's number (Re number) on operating characteristics of hydraulic turbomachinery.
- Recalculation of operating characteristics from the model to the main (improved) machine design.

Model and experimental research into pumps.
- Laboratory test sets for measurement of pump operating and cavitation characteristics.
- Elements of the test set and measuring equipment.
- Experimental research into pump operating and cavitation characteristics.

Model and experimental research into water turbines.
- Laboratory test sets for measurement of water turbine operating and cavitation characteristics.
- Elements of the test set and measuring equipment.
- Method of measuring the universal operating characteristics of turbines and cavitation coefficient in all operating regimes.

Model and experimental research into fans.
- Laboratory test sets for experimental research into fans.
- Testing procedures.

Model and experimental research into flow through profile cascades.
- Laboratory test sets for experimental research into profile cascades.

Guided independent research
- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate model considered in the problem presented in the doctoral dissertation.

Recommended literature

1. Lewis R. I., **Turbomachinery performance analysis**, Elsevier Science & Technology Books, 1996.
2. Богдановић Б., Миленковић Д., Богдановић-Јовановић Ј., **Вентилатори - радне карактеристике и експлоатациона својства [Fans – operating characteristics and exploitation properties]**, Машински факултет Ниш, 2006.
3. Michael Volk, **Pump Characteristics and Applications,** Taylor & Francis, California, U.S.A.,2005.
4. Shao Lee Soo, **Instrumentation for fluid particle flow**, Noyes Publications, 1999.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MODERN MANAGEMENT CONCEPTS, METHODS AND TOOLS**
Professor/professors:	Peđa M. Milosavljević
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introduction to modern concepts, methods and tools of management that managers use in conditions of global competition. Introduction to examples from manufacturing and service organization, allowing better understanding of the importance of management and introduction to advanced techniques and technologies for making decisions and solving problems.

Course outcome

Acquiring current knowledge in the field of management and the ability of students to contribute to the improvement of existing processes and the development of new ones, as well as their willingness to apply their knowledge in the engineering sector and theoretical work. Students are trained for process management and decision-making, using modern methods and management tools.

Course content

Theory classes

- The current state in the field of management and development trends for the future;
- Excellence models;
- Process management;
- Measurement of process performance;
- Integrated management systems;
- Quality tools;
- Management tools;
- Lean concept;
- Leadership;
- Kaizen philosophy;
- Six Sigma method;
- Advanced tools and methods for process analysis;
- Management of maintenance systems.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of industrial management.

Recommended literature

1. Милосављевић П., **Инжењерски менаџмент [Engineering management]**, уџбеник, Машински факултет Универзитета у Нишу, 2015.
2. Стојиљковић В., **Lean у здравству: концепт менаџмента за трансформацију здравствених система у условима кризе [Lean in health care: A management concept for the transformation of health care systems in crisis conditions]**, Despot Book, Ниш, 2013.
3. Имај М., **Каизен, кључ јапанског пословног успеха [Kaizen, the key to the Japanese business success]**, Моно и Мањана, Београд, 2008.
4. Стојиљковић В., Милосављевић П., и др., **Индустријски менаџмент [Industrial management]**, практикум, Машински факултет Универзитета у Нишу, 2010.
5. Милосављевић П., **Одржавање техничких система по концепту TPM и Six Sigma [Maintenance of technical systems in accordance with the TPM and Six Sigma concepts]**, монографија, Задужбина Андрејевић, Београд, 2007.
6. Стојиљковић В. и др., **Интегрисани системи менаџмента [Integrated management systems],** CIM College и Машински факултет Ниш, 2006.
7. Womack P. J., Jones T. D., **Lean Thinking: Banish Waste and Create Wealth in your Corporation**, Free Press, New York, 2003.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN CENTRAL HEATING, DISTRICT HEATING AND GAS ENGINEERING**
Professor/professors:	Velimir P. Stefanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to systems of central and district heating and studying basic principles for designing elements and installations of central and district heating, as well as for calculating gas pipeline elements and systems.
- The course includes the basics of building construction. This is primarily related to technical regulations of process and gas engineering, project development, selection of standard equipment and safety requirements.
- Students master methods for calculating and choosing standard equipment, design and implementation procedures, testing and control.

Course outcome

After the exam is passed, students will be able to independently apply the methodology of calculations of most commonly used central and district heating installations, and gas pipeline systems and elements in engineering practice.

Course content

Theory classes

- Introduction, classification and areas of application of central and district heating systems;
- Calculation of amount of heat needed for heating;
- Hydraulic and thermodynamic calculation of heating networks in central and district heating systems;
- Hydraulic regime of heating networks in central and district heating systems;
- Design and construction solutions of heating networks in central and district heating systems;
- Hydraulic calculation of gas pipelines in isothermal flow;
- Design and implementation specificities of LPG installations;
- Renewable sources and possibilities of application in central and district heating systems;
- Design of gas installations and MMRS – main metering and regulating stations, and selection of standard equipment;
- Selection of optimal pipeline parameters such as route, diameter, material quality and pressure class.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper directly correlated with the adequate model considered in the problem presented in the doctoral dissertation.

Recommended literature

1. Стефановић В., **Грејање, топлификација и снабдевање гасом [Heating, district heating and gas supply]**, Машински факлултет Ниш, 2011.
2. Тодоровић Б., **Пројектовање постројења за централно грејање [Design of central heating plants]**, Београд, 1996.
3. Кулић Е., **Принципи пројектовања система гријања [Design principles of heating systems]**, Сарајево, 1989.
4. Reknagel, Šprenger, **Грејање и климатизација [Heating and air conditioning]**, Врњачка Бања, 2002.
5. Фангер О., **Thermal confort**, Copenhagen, 1970.
6. Соколов Ј., **Топлификација и топлотне мреже [District heating and thermal networks]**, Београд, 1985.
7. Толмач Д., Булик Д., Радуловић Р.: **Елементи пројектовања (ГМРС) – главних мерно регулационих станица за природни гас [Design elements (MMRS) – main metering and regulating stations for natural gas]**, "СМ" Инжењеринг, Зрењанин, 2005.
8. Поповић С., **Приручник за пројектовања и израду МРС на природни гас [Handbook for design and construction of MRS for natural gas]**, Београд, 1999.
9. Јовановић П., **Гасоводи и гасне инсталације [Gas pipelines and installations]**, Београд, 2003.
10. Муштовић Ф., **Течни нафтни плин [Liquefied petroleum gas]**, Београд, 1974.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, consultations and guided independent research.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN AIR CONDITIONING**
Professor/professors:	Marko G. Ignjatović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Expanding the knowledge of students in the field of complex air conditioning systems in buildings with specific requirements, modelling and simulation of energy performance of air-conditioned buildings and operational optimization of air conditioning systems.

Course outcome

Students acquire knowledge of complex air conditioning systems, monitoring and control systems, and efficient energy supply of buildings, as well as certain competences for independent scientific research including the writing of the doctoral dissertation.

Course content

Theory classes

- Indoor air quality
- Thermal comfort
- Air distribution in air-conditioned spaces
- Air conditioning systems with variable air volume
- Air filtration and clean rooms
- Air conditioning systems in hospitals
- Air conditioning systems in the pharmaceutical industry
- Air conditioning systems in hotels
- Automated regulation and control in air conditioning systems
- System integration into a building and BMS
- Energy consumption in air conditioning systems

Guided independent research

- Modelling of energy needs of a building, efficient energy supply and optimization of air conditioning systems.
- Training in a designed representative building including the analysis of the air conditioning system operation.

Recommended literature

1. **2019 ASHRAE Handbook - HVAC Applications**, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2011, USA
2. **2016 ASHRAE Handbook - Systems and equipment**, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2012, USA
3. **2017 ASHRAE Handbook - Fundamentals**, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2013, USA
4. **Building Performance Simulation for Design and Operation**, edited by Jan Hensen and Roberto Lamberts, Spon Pres, 2011, Canada

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, consultations and guided independent research. Training in a designed representative building.

Knowledge assessment (maximum number of points 100)

Term paper (50 points), presentation and analysis of the training building system (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN THERMAL ENERGY PLANTS**
Professor/professors:	Dragoljub S. Živković, Dejan M. Mitrović, Mirjana S. Laković Paunović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to various phenomena occurring during variable and unsteady operating regimes of thermal energy plants and methods that should provide their safe and reliable operation.
- Enabling students to independently study and solve problems of various phenomena based on scientific principles, define relevant physical and mathematical models, and perform optimization of processes, equipment and operating regimes of thermal energy plants.

Course outcome

Acquired necessary knowledge to be used by students in scientific research in the field of thermal energy plants.

Course content

Theory classes

- Variable operating regimes and energy efficiency of thermal energy (TE) plants.
- Unsteady operating regimes of TE plant.
- Problems of interaction between the working substance and the structure of TE plants.
- Operational safety of TE plants.
- Reliability of parts of TE plants.
- Combined production of heat and power.
- Problems of automated regulation of TE plants.
- Mathematical modelling and numerical simulation of operation of TE plants.
- Impact of TE plants on the environment. Problems of soil, water and air pollution.
- Design methods of modern TE plants.
- Experimental, operational and reception testing of TE plants.
- Techno-economic optimization of processes, equipment and operating regimes of TE plants.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate problem considered in the task presented in the doctoral dissertation.

Recommended literature

1. Kotljar I.V., **Perehodnye Processy V Gazoturbinyh Ustanovkah**, Mašinostrenie, Leningrad, 1973., s.253.
2. Ivanov V.A., **Stacionarnie i Perehodnie Režimi Moščnih Paroturbinnyh Ustanovok**, Energija, Leningrad, 1971., s.280.
3. Šarovarov G.A., **Fizika Nestacionarnih Processov AES**, Nauka i tehnika, Minsk, 1985., s. 208.
4. **EDUCOGEN-European Educational Tool for Cogeneration**, European Commission, National TechnicalUniversity of Athens, Greece, University of Dundee, UK, 2001.
5. Nuorkivi A., **Institutional Handbook for Combined Heat and Power Production with District Heating**, Helsinki University of Technology, Finland, 2002.
6. Joseph A. Orlando, **Cogeneration Desin Guide**, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1996.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (75 points) and oral exam (25 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THERMAL ENGINEERING PROCESSES AND DEVICES IN INDUSTRY AND BUILDING CONSTRUCTION**
Professor/professors:	Branislav V. Stojanović, Dejan M. Mitrović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to the course content on renewable energy sources and enabling them to independently apply scientific methods in treating problems of renewable energy sources.
- Acquiring knowledge in specific areas of design, modelling and exploitation of steam boilers.
- Enabling students to: systematically study energy systems in buildings and industry, examine possibilities for improving energy efficiency of said energy systems and devise systems for energy flow management.

Course outcome

Acquiring necessary knowledge that students will use in their scientific research in the field of thermodynamic processes and devices in industry and building construction.

Course content

Theory classes

- **Renewable energy sources**

Biomass energy. Solar energy. Geothermal energy.

- **Power and heat generation processes from renewable energy sources**

Autonomous and hybrid systems.

- **Steam and hot water boilers**

Development tendencies of modern energy engineering. Structural optimization of steam and hot water boilers. Technological solutions of steam and hot water boilers. Basic concepts and definitions of thermohydraulic parameters of two-phase media. Heat exchange modes in heating, evaporation and overheating of working fluids or heat carriers. Modelling and simulation of unsteady operation of boilers. Furnaces for fuel combustion in a fluidized bed. Temperature regulation of overheated steam. Reconstruction and revitalization of boilers.

- **Energy efficiency in industry and building construction**

Boiler as a heat source in an energy system. Accompanying energy systems for heating, ventilating and air conditioning. Building as a whole, building cladding and thermal characteristics of cladding. Energy balance. Identification of parameters and modelling of unsteady system processes. Improvements in energy efficiency of devices for thermal energy production and systems for energy distribution and cost reduction. Intelligent systems. Cost benefit analysis (financial analysis, economic analysis, risk analysis).

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate problem considered in the task presented in the doctoral dissertation.

Recommended literature

1. John Twidell, Tony Weir, (2005), **Renewable Energy Resources**, 2nd Edition, Publisher: Taylor and Francis, ISBN-10: 0419253300, (ISBN-13: 978-0419253303).
2. Bent Sorensen, (2004), **Renewable Energy**, 3rd Edition, Publisher: Academic Press, ISBN-10: 0126561532, (ISBN-13: 978-0126561531).
3. Đurić, **Parni kotlovi [Steam boilers]**, Građevinska knjiga Beograd, 1969.
4. Gulič, Brkić, Perunović, **Parni kotlovi [Steam boilers]**, Mašinski fakultet, Beograd 1988.
5. Brkić, Živanović, **Termički proračun parnih kotlova [Thermal calculations of steam boilers]**, Mašinski fakultet, Beograd 1981.
6. Morvay, Z, Gvozdenac, D., **Applied Energy and Environmental Management**, John Wiley and Sons, 2008.;
7. Драган Марковић, **Процесна и енергетска ефикасност [Process and energy efficiency]**, Београд, 2010.;
8. John Gibons, **Building Energy Efficiency**, U.S. Congress, Office of Technology Assessment, Washington, 1992.;

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (75 points) and oral exam (25 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN THEORY OF DRYING**
Professor/professors:	Mladen M. Stojiljković, Jelena N. Janevski
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to the theory of heat and mass transfer in the drying process, drying techniques, heat dryer calculation, certain types of dryers, mathematical modelling as a basis for the design, calculation and construction of dryers.
- Enabling students to independently and on scientific principles resolve heat and mass transfer phenomena in the drying process and define the appropriate models for mathematical modelling of these processes, as part of their work on the doctoral dissertation.

Course outcome

Acquiring the necessary knowledge of heat and mass transfer in the drying process, which will be used both in scientific research and for modelling, design, calculation and construction of dryers.

Course content

Theory classes

- **Wet material drying**
  Moist materials, humidity and drying agents. Forms of binding moisture content. Methods for determination of moisture content. Division of moist materials. Phenomena during wet material drying.
- **Kinetics of thermal drying**
  Flux density and potential gradient. Thermal drying and thermodynamics of irreversible processes. Velocity of thermal drying. Basic equations of kinetics of thermal drying.
- **Heat and moisture transfer during material drying**
  Heat and moisture transfer under the dominance of external resistance. Heat and moisture transfer under the dominance of internal resistance.
- **Thermodynamics of convective drying**
  Mass balance for the drying process. Energy balance during convective drying. Recirculation of gaseous drying agents. Theoretical and real convective dryers. Thermodynamic analysis of convective drying.
- **Drying with unsaturated moist air**
  Characteristic values of moist air. Thermodynamic diagram of moist air. Characteristic changes in moist air during the operation of convective dryers.
- **Method of thermal drying of moist materials**
  Fields of temperature and moisture content in wet materials.
- **Preparation for thermal drying of wet materials and choice of dryer**
- **Thermal drying and the aggregate state of wet materials**
  Thermal drying of: pieces of wet solid materials, wet liquid materials, wet materials in paste form. Dispersion characteristics of moist materials.
- **Technological bases for designing convective dryers**
  Rotary dryers for wet materials. Dryers with conveyors. Fluidized bed dryers. Pneumatic dryers. Dryers with dissipation of wet materials.

Guided independent research

- Preparing students to do research within their doctoral dissertation, by writing a term paper that deals with problems in drying, according to the problem presented in the doctoral dissertation.

Recommended literature

1. Ликов А. В., **Теорија сушки**, Енергија, Москва, 1968.
2. ТопићР., **Сушење и сушаре [Drying and dryers],** СМЕИТС, Београд, 2014.
3. Topić R., **Osnovi projektovanja, proračuna i konstruisanja sušara [Basics of design, calculation and construction of dryers]**, Naučna knjiga, Beograd, 1989.
4. Valent V., **Sušenje u procesnoj industriji [Drying in process industry]**, Tehnološko metalurški fakultet Beograd, 2001.
5. Ликов М. В., **Сушка в химическoj промишлености**, Химија, Москва, 1970.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points), after the defence of the independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN REFRIGERATION DEVICES AND HEAT PUMPS**
Professor/professors:	Goran D. Vučković, Mirko M. Stojiljković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Expanding students' knowledge related to the application of refrigeration devices and heat pumps in energy systems. Enabling students to perform mathematical modelling, simulation and optimization of energy systems with refrigeration devices and heat pumps, as well as for use appropriate software solutions.

Course outcome

Students acquire knowledge of refrigeration devices and heat pumps required for their application and estimation of possibilities for energy efficiency improvement and environmental impact reduction, as well as competences for independent scientific research.

Course content

Theory classes

- Compressor chillers and heat pumps. Working characteristics. Operation automation
- Absorption refrigeration. Absorption chillers. Working characteristics. Connections with cogeneration systems. Connections with solar systems
- Energy accumulators
- Exergy analysis of refrigeration devices and heat pumps
- Mathematical modelling and optimization of energy systems with refrigeration devices and heat pumps
- Heat pumps in district heating systems
- Refrigeration devices and heat pumps in buildings
- Industrial refrigeration
- Food refrigeration and freezing. Cold chain
- Deep refrigeration

Guided independent research

- Preparing students to independently research scientific and professional literature
- Software solutions for synthesis and simulation of refrigeration devices and heat pumps
- Modelling of energy systems with refrigeration devices and heat pumps
- Determination of energy, environmental and economic indicators

Recommended literature

1. Hundy G.F., Trott A.R., Welch T.C., **Refrigeration, Air Conditioning and Heat Pumps**, Elsevier / Butterworth-Heinemann, 2016.
2. Вујић С., **Расхладни уређаји [Refrigeration devices]**, Универзитет у Београду, Машински Факултет, Београд, 1991.
3. Маркоски М., **Расхладни уређаји [Refrigeration devices]**, Универзитет у Београду, Машински Факултет, Београд, 2006.
4. Гвозденац Д., Вањур И., **Расхладна техника [Refrigeration]**, ФТН Издаваштво, Нови Сад, 2010.
5. 2019 ASHRAE Handbook—**HVAC Applications**, ASHRAE, Atlanta, Georgia, USA, 2019.
6. 2018 ASHRAE Handbook—**Refrigeration**, ASHRAE, Atlanta, Georgia, USA, 2018.
7. 2017 ASHRAE Handbook—**Fundamentals**, ASHRAE, Atlanta, Georgia, USA, 2017.
8. 2016 ASHRAE Handbook—**HVAC Systems and Equipment**, ASHRAE, Atlanta, Georgia, USA, 2016.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, supervision, term papers, independent research.

Knowledge assessment (maximum number of points 100)

Term paper (30 points), independent research (40 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN THEORY OF SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL PROTECTION**
Professor/professors:	Gordana M. Stefanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Preparing students for independent scientific and professional work in the field of sustainable development and environmental protection.
- Students will be introduced to the existing theoretical and latest research achievements in the field of sustainable development in order to be able to objectively, systematically and critically study the phenomena and problems in the economic, social and environmental sphere, as well as their relationship and interactions.

Course outcome

Acquiring competence for thorough knowledge and understanding of the concept of sustainable development and problem solving using scientific methods and procedures. Linking basic knowledge in various fields related to economic and social development and environmental protection, their practical application, but also the monitoring of modern achievements in the field, particularly for independent research and achievement of scientific and applied results in the field of sustainable development and environmental protection, by applying the latest research methods with a critical evaluation of research results obtained by others.

Course content

Theory classes

- Concept of sustainable development. History of sustainable development.
- Resources, the environment and economic development.
  Relation between economic growth and environmental protection.
- Social well-being and sustainable development.
  Concept of production, social wealth, growth and development.
  Factors of social welfare.
- Economic aspect of sustainable development.
  "Green" economy. Paths for achieving a "green" economy: "harmful subsidies", "green taxes".
- State of the environment and sustainability.
  Dimensions of sustainability.
  Principles and standards of sustainability.
- Air, water and soil protection. Principles and technologies.
- Influence of energy engineering and certain branches of process industry on the environment.
- Sustainable development of energy engineering.
- Urban sustainability.
- Indicators of sustainable development, sustainability index.
- Multi-criteria analysis as a tool for assessing sustainability.
- Overview of methods used in multicriteria decision-making

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper on the topic directly correlated with the adequate problem considered in the task presented in the doctoral dissertation.

Recommended literature

1. Mark Roseland (2005), **Toward Sustainable Communities**, Ney Society Publishers, Canada
2. Milutinović, S. (2012). **Politike održivog razvoja [Sustainable development policies]**. Niš: Fakultet zaštite na radu
3. Trputec Z. (2007), **Dizajn humanog održivog razvoja [Design of humane sustainable development]**, Hrvatski leksikografski institut BiH, Mostar
4. Ekins, P. (2000). **Economic Growth and Environmental Sustainability**. London: Routledge
5. Harris, J. M. (2006). **Environmental and Natural Resource Economics: A Contemporary Approach.** 2nd edition. Houghton Mifflin Company
6. S.E. Jergensen, B. Halling-Sorensen, S.N. Nilsen, ***Handbook of Environmental and Echological Modeling***, 2003
7. N.P. Cheremisinoff, **Hanbook of Solid Waste Management and Waste Minimisation Technologies**,

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**HEAT AND MASS TRANSFER IN FLUIDIZED SYSTEMS**
Professor/professors:	Branislav V. Stojanović, Mića V. Vukić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

- Introducing students to hydrodynamics and heat and mass transfer in fluidized systems.
- Enabling students to independently and on scientific principles review and explain heat and mass transfer phenomena in fluidized systems and create appropriate models for mathematical modelling of these processes, as part of their work on the doctoral dissertation.

Course outcome

Acquired knowledge of hydrodynamics and heat and mass transfer in fluidized systems.

Course content

Theory classes

- General characteristics of a fluidized bed:
  - Fluidization phenomenon;
  - Bed porosity;
  - Pressure drop in a bed;
  - Minimum fluidization velocity;
  - Velocity of solid particles removal and limits of fluidized bed existence;
  - Characteristics of bubbles;
  - Expansion of a fluidized bed;
  - Mixing and circulation of solid particles in a fluidized bed;
  - Fluidization models.
- Heat exchange between solid particles and a fluidization agent.
- Characteristics of mass exchange in a fluidized bed.
- Heat exchange between a fluidized bed and surface.
- Practical application of a fluidized bed:
  - Drying in a fluidized bed;
  - Combustion in a fluidized bed.
- Basic characteristics of fluidized bed apparatus.
- Designing equipment for processes in gas - solid particles systems.

Guided independent research

- Preparing students to do research within their doctoral dissertation, by writing a term paper that deals with problems in heat and mass transfer in a fluidized bed, according to the problem presented in the doctoral dissertation.

Recommended literature

1. Stojiljković Mladen, **Prenos toplote u fluidizovanom sloju [Heat transfer in a fluidized bed]**, Mašinski fakultet Univerziteta u Nišu,, Niš, 2019.
2. Oka N. Simeon, **Sagorevanje u fluidizovanom sloju – procesi i primena [Combustion in a fluidized bed – processes and application]**, Jugoslovensko društvo termičara, Beograd, 1994.
3. Davidson J.F., Harrison D., **Fluidization**, Academic Press, London and New York, 1971.
4. Kunii D., Levenspiel O., **Fluidization Engineering**, John Wiley & Sons INC., NewYork, 1969.
5. Гелперин Н.И., Ајнштејн В. Г., Кваша В.Б., **Основи техники псевдоожижениja**, Химиja, Москва, 1967.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (50 points). The requirement for taking the exam is the defended independently written term paper (50 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**STOCHASTIC PROCESSES IN MECHANICAL SYSTEMS**
Professor/professors:	Goran B. Janevski
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the basics of the theory of random vibration and processes in mechanical systems.

Course outcome

Acquiring knowledge in the theory of random vibration.

Course content

Theory classes

- The axioms of probability.
- Characteristics of a random variable.
- Examples of distribution functions and probability density.
- Reliability of mechanical systems exposed to random effects.
- Common features of two or more random variables.
- Reliability of mechanical systems exposed to several random variables.
- Basic theory of random functions.
- Random fluctuations of discrete mechanical systems.
- Random fluctuations of continuous mechanical systems.

Guided independent research

Preparing students to do research within their doctoral dissertation.

Recommended literature

1. Isaac Elishakoff, **Probabilistic Theory of Structures**, Dover Publication, Inc. Mineola, New York Second Edition, 1998.
2. Wei-Chau Xie, **Dynamic Stability of Structures**, Cambridge, University Press, 2006.
3. A. Papoulis, **Probability, random variables and stochastic processes,** McGrow Hill, 1984.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Theory classes, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THEORY OF PLATES AND SHELLS**
Professor/professors:	Julijana D. Simonović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to stresses and strains in surface structures, as well as vibration and stability of composite structures.

Course outcome

Acquiring knowledge of stress and strain state analysis, as well as vibration and stability of surface and composite structures.

Course content

Theory classes

- **Bending of a long rectangular plate into a cylindrical surface.** Differential equations for cylindrical bending of plates. Cylindrical bending of an equally loaded free supported rectangular plate, fixed rectangular plate, rectangular plate with flexible fixed ends. **Pure plate bending.** The slope and curvature of small deflection plate. Relationship between offensive moments and curvature in pure plate bending. Different cases of pure bending. Energy of deformation. **Symmetrical bending of circular plates.** Differential equations for symmetrical bending of transversely loaded circular plates. Uniform load of plates, concentric, centre load. Plate with a round hole in the centre. **Small deflections of transversely loaded plates.** Differential equation of the elastic surface. Contour conditions. Another method of performing boundary conditions. The reduction of the plate bending problem to the membrane bending problems. **Free supported rectangular plates.** Plates loaded by sinus area. Navier-type solution. Maurice-Levy's solution. Plates loaded by various loads. **Rectangular plates with different boundary conditions.** Rectangular plate bending by moments along its side. **Continuous rectangular plates. Plates on elastic foundation.** Rectangular and continuous plates on elastic foundation. **Bending of anisotropic plates.** Differential equations of curved plates. Determination of stiffness for various special cases. Application of the theory to lattice calculations. Bending of rectangular plates. **Bending of the panels due to cross-load complex flat tension.** Differential equations. Energy method.
- **Shell deformation at which no bending occurs.**
- **General theory of cylindrical shells.**
- **Shell-shaped rotating surfaces loaded symmetrically to their axis.**

Vibration of composite plates.

- Basic differential equations of bending and vibration. Constraints and assumptions. Boundary conditions. Differential equations of bending of composite plates. Differential equations of vibration of composite plates. Bending and vibration of specially orthotropic, symmetric angled, antisymmetric transverse and antisymmetric angled simply supported laminated plates. Determination of stability conditions of plates subjected to constant pressure forces in the plate plane. Determination of plate eigenfrequencies.

Vibration of composite shells.

- Basic differential equations of bending and vibration. Constraints and assumptions. Boundary conditions. Differential equations of bending of composite shells. Differential equations of vibration of composite shells. Bending and vibration of specially orthotropic and antisymmetric transverse simply supported laminated cylindrical shells. Determination of stability conditions of shells subjected to constant axial and radial forces. Determination of eigenfrequencies of laminated cylindrical shells.

Guided independent research

- Preparing students to conduct research within their doctoral dissertation.

Recommended literature

1. Timošenko S., Goodier J.N., **Ploče i ljuske [Plates and shells]**, Građevinska knjiga, Beograd, 1962.
2. Jones M.J., **Mechanics of composite materials**, McGraw-Hill Book Company, Washington, 1975.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Theory classes, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**DYNAMICS OF NANOSTRUCTURES**
Professor/professors:	Ivan R. Pavlović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge in the field of dynamics of nanosystems.

Course outcome

Students acquire knowledge that enables them to independently model and simulate various types of nanosystems.

Course content

Theory classes

- Motion. Strain and rotation measures. Strain tensor invariants. Time component of tensors. Strain compatibility conditions. Various problems.
- Introduction to the nonlinear theory of elasticity. Linear constitutive equations. Lattice dynamics as the foundation of linear elasticity. Material stability. Field equations of nonlocal linear elasticity. Uniqueness theorem. Power and energy. Reciprocal theorem. Variational principles. Approximate models. Screw dislocation. Edge dislocation. Dislocation in nonlocal hexagonal elastic solids. Distribution of dislocations. Nonlocal stress field at the Griffith crack. Line crack subjected to shear. Interaction of a dislocation with a crack. Interaction between defects and dislocations. Somigliana-type dislocation. Fundamental solution. Nonlocal elastic half-plane. Rigid stamp on a nonlocal elastic half-space.
- Nonlocal beam theory. Nonlocal Euler-Bernoulli beam theory. Nonlocal Timoshenko beam theory. Nonlocal Reddy beam theory.
- Strain gradient theory. First order strain gradient theory. Higher order strain gradient theory.
- Mathematical modeling and simulation of nanosystems using the MATLAB software.

Recommended literature

1. Eringen A. C., **Nonlocal Continuum Field Theories**, Springer-Verlag New York, 2001.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term paper up to 40 points. Final exam up to 60 points. The exam is considered passed if a student achieves more than 55 points.

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SIMULATION IN MECHANICAL DESIGN**
Professor/professors:	Boban R. Anđelković, Milan S. Banić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course syllabus trains students in various types of advanced simulation technologies in the process of product development. The course objective is for students to independently master the use of advanced simulation technologies as part of their work on their doctoral dissertation.

Course outcome

Students are capable of choosing the right technique for analysing or simulating the behaviour of mechanical systems and applying it in the process of product design and development. After developing practical examples, students acquire the necessary knowledge and experience to independently apply said techniques in analysing and simulating mechanical behaviour of structures.

Course content

Theory classes

- Introduction to advanced engineering simulations.
- Verification and validation in engineering simulation.
- Simulations of mechanical systems by applying the Simulink, SimMechanics, MatLab packages. Model formation, definition of components, links, environment effects, component interactions, deviations, static and dynamic analysis of system behaviour.
- Simulations of nonalgorithmic and unknown mechanical systems. Artificial neural networks. Fuzzy decision-making systems.
- Nonlinear analysis by applying the finite element method. Application of the finite element method in simulations of creeping, viscoelasticity, contact problems and geometric nonlinearity.
- Dynamic analysis by applying the finite element method. Application of the finite element method in problems with transient phenomena, frequency response analysis, random and harmonic excitations. Nonlinear dynamics. Explicit analysis.
- Fatigue and fracture mechanics by applying the finite element method. Fatigue analysis in dynamically loaded structures by applying the finite element method.
- Structural optimization by applying the finite element method: optimization of dimensions, shapes, topological optimization, robust optimization, optimization of dynamic systems.
- Basics of computational fluid dynamics.
- Multiphysical analyses. Sequential and full coupling of multiphysical analyses. Thermomechanical analysis. Solid and fluid interaction analysis.

Guided independent research

- Preparing students to independently apply simulations as part of their work on their doctoral dissertation.

Recommended literature

1. Zienkiewicz, O., Taylor, R., Zhu, J. Z**., The Finite Element Method: Its Basis and Fundamentals**, 7 edition, Butterworth-Heinemann; Oxford, 2013.
2. Huei-Huang L.: **Finite Element Simulations with ANSYS Workbench** 19, SDC Publications, 2019.
3. Danila C., **Hands-On Ansys Workbench**, Nothing Else **-** Volume 1 – 3, www.expertfea.com

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**SELECTED TOPICS IN POWER TRANSMISSION**
Professor/professors:	Jelena D. Stefanović-Marinović, Aleksandar V. Miltenović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Introducing students to the latest design solutions in the field of mechanical transmission – reducers and multipliers, their implementation, calculation and analysis.

Course outcome

The ability to interpret the direction of power transmission development, as well as the choice, calculation and design of mechanical transmission as a concrete task.

Course content

Theory classes

- Classification, characteristics and application of reducers and multipliers.
- Advantages and disadvantages of different designs.
- Modular design principle in reducers and multipliers.
- Planetary gear transmission as reducers and multipliers.
- Transmission with a variable transmission ratio. Continuous and step changes – variators and gearboxes.
- Recent design solutions of mechanical transmission (harmonic drive, cycloid geared transmission, etc.).
- Special mechanical transmission (transmission with great transverse contact ratio; transmission with special non-involute tooth gearing; transmission for robots, transmission for shaft generators, turbine transmission, etc.).

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of power transmission.

Recommended literature

1. Radzevich S.: **Theory of Gearing: Kinematics, Geometry, and Synthesis**, CRC Press, 2017
2. Kerle H, Corves B, Hüsing M,: Getriebetechnik, Grundlagen, **Entwicklung und Anwendung ungleichmäßig übersetzender Getriebe**, Springer, 2015
3. Танасијевић, С., Вулић А.: **Механички преносници [Mechanical transmission]**, Крагујевац, 2006.
4. Стефановић-Мариновић J.: **Механички преносници - Планетарни преносници [Mechanical transmission – planetary gear transmission]**, Ниш, 2017.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (30 points). The requirement for taking the exam is the defended independently written term paper (70 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**INTELLIGENT MANUFACTURING SYSTEMS AND TECHNOLOGIES (IMSAT)**
Professor/professors:	Miodrag T. Manić, Milan B. Trifunović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of intelligent manufacturing systems and technologies and Industry 4.0. Developing the ability for conceptual design and implementation of intelligent manufacturing systems and technologies. Analysing the structure of an intelligent technological system, which is based on multiagent methodology. Understanding and conceiving smart products.

Course outcome

Students acquire knowledge that enables them to independently research, analyse and model intelligent manufacturing systems and technologies in the Industry 4.0 concept. They should understand the interaction between software and hardware IMSAT subsystems, intelligent robots and control systems in the manufacturing environment.

Course content

Theory classes

- Industrial systems for various purposes with CNC and DNC control.
- Intelligent machining. Digital manufacturing and e-manufacturing.
- Industrial robots, intelligent mobile robots. Control of CNC machines and intelligent and independent robots by using artificial intelligence and machine learning.
- Software support and IMSAT integration.
- Measurement and control systems and monitoring and diagnostics systems in IMSAT.
- Virtual manufacturing systems. Virtual reality. Machine learning.
- Intelligent manufacturing systems. Expert systems and artificial intelligence systems.
- IMS termination. Just-in-Time and Lean concepts.
- Internet of Things and smart products.
- Industry 4.0.

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of IMSAT. Conception and design of IMSAT.

Recommended literature

1. Andrew Kusiak, **Intelligent manufacturing systems**, Prentice Hall, 1990
2. Mohammed Jamshidi, **Design and Implementation Of Intelligent Manufacturing Systems**: From Expert Systems, Neural Networks, To Fuzzy Logic, Pearson Education, 2008
3. Mikell P. Groover**, Automation, Production Systems, and Computer-integrated Manufacturing**, Prentice Hall, 2007
4. R. Bick Lesser**, Intelligent Manufacturing: Reviving U.S. Manufacturing Including Lessons Learned from Delphi Packard Electric and General Motor**s, Productivity Press, 2013
5. http://www.ims.org/publications/
6. Fran Yáñez, **The 20 Key Technologies of Industry 4.0 and Smart Factories: The Road to the Digital Factory of the Future**, Kindle eBook, https://www.amazon.com/dp/B0784TF8YX
7. Diego Galar Pascual, Pasquale Daponte, Uday Kumar**, Handbook of Industry 4.0 and SMART Systems**, CRC Press, 2019., ISBN 9781138316294

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**PROCESS MODELLING AND OPTIMIZATION**
Professor/professors:	Miroslav R. Radovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge and skills in the field of process modelling and optimization.

Course outcome

Competence of students to model and optimize processes.

Course content

- Preliminaries. Process classification.
- Process modelling. Process analysis. Process performance and factors. Theoretical forms of mathematical performance models. Analysis of factor influence on process performance. Choice of performance and factors for creating mathematical process models. Choice of mathematical model forms.
- Process modelling methods. Analytical process modelling. Process modelling based on the theory of dimensionality. Numerical process modelling. Stochastic process modelling. Process modelling using mathematical models of the first and higher orders. Analysis of the adequacy of mathematical models. Software for mathematical process modelling.
- Process optimization. Process optimization strategy. Structure of optimization models. Objective functions, state functions and process constraints. Criteria for process optimization. Selection of mathematical models for process optimization.
- Process optimization methods. Direct optimization. Adaptive optimization. Single-objective optimization. Multi-objective optimization. Software for solving optimization tasks.
- Examples of process modelling and optimization.

Guided independent research

- Preparing students to independently research, model and optimize processes.

Recommended literature

1. Радовановић М., Мадић М., **Планирање и анализа експеримената [Design and analysis of experiments],** Машински факултет, Ниш, 2019.
2. Јурковић М., **Математичко моделирање инжењерских процеса и система [Mathematical modelling of engineering processes and systems],** Машински факултет, Бихаћ, 1999.
3. Yoshimura M., **System Design Optimization for Product Manufacturing,** Springer, 2010.
4. Montgomery D., **Design and Analysis of Experiments**, John Willey & Sons, Arizona State University, 2001.
5. Станић Ј., **Увод у теорију техноекономске оптимизације [Introduction to the theory of techno-economic optimization]**, Машински факултет, Београд, 1988.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, demonstration of software tools, practical work with students on problem solving, term paper.

Knowledge assessment (maximum number of points 100)

Term paper with defence (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**TIRE BEHAVIOUR SIMULATION**
Professor/professors:	Nikola D. Korunović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Providing students with the necessary level of knowledge of modern methods of computer-aided simulation of mechanical behaviour of tires, in order to introduce them the challenges in the given field and prepare them for future research and development. The acquired level of knowledge is recommended for the position of a leading tire designer and developer or tire testing engineer.

Course outcome

Student will be able to:

- independently perform simulation of tire inflation, tire footprint analysis, acceleration and braking analysis, and steady-state cornering analysis,
- model tire materials (rubber, steel and textile cord) for the purpose of FEM-based stress analysis, as well as perform necessary laboratory testing of specimens from said materials,
- apply laboratory tire testing methods necessary for verification of numerical results.

Course content

Theory classes

- Nonlinearities in FEM-based stress analysis of tires and stress analysis principles
- Rubber modelling for the purpose of FEA of tires
- Modelling of textile and steel cord
- Geometric tire models suitable for the creation of models for stress analysis (FEM model)
- FEM tire models
- Simulation of tire inflation using an axisymmetric FEM model
- Simulation of a vertically loaded tire behaviour using a 3D FEM model
- Simulation of acceleration and braking in a straight
- Steady-state cornering simulation
- Term paper: creation of a FEM model for the given type of tire and simulation of its behaviour in tire inflation, static loading, braking, acceleration and cornering.

Guided independent research

- Research in the given area, writing a term paper.
- Typical elements of scientific research related to analysis and simulation in tire behaviour. Writing a paper for a scientific conference or a scientific journal.

Recommended literature

1. Gent, A. N., i Walter, J. D., **The Pneumatic Tire**. Washington D.C.: National Highway Traffic Safety Administration, U.S. Department of Transportation.
2. Никола Коруновић, **Анализа стационарног котрљања пнеуматика применом метода коначних елемената [Steady-state rolling tire analysis using the finite element method]**, докторска дисертација, Машински факултет у Нишу
3. Никола Коруновић, **Статичка анализа понашања аутомобилског пнеуматика методом коначних елемената [Static analysis of automobile pneumatic tire behaviour using the finite element method]**, магистарска теза, Машински факултет у Нишу
4. Selected scientific papers.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Classes are held in a consultative manner and through interactive cooperation with the advisor and, optionally, with the appointed supervisor from the industry. The advisor introduces students to the course content directly. After being introduced to the course content, each student, in cooperation with the supervisor, chooses a topic for the project task and works on it. It is expected that the final result of the work on the project task is a manuscript, recommended for presentation at an international scientific conference.

Knowledge assessment (maximum number of points 100)

Term paper (70) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MODELLING, IMPLEMENTATION AND MANAGEMENT OF ENGINEERING PROCESSES**
Professor/professors:	Dragan T. Mišić
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

The course objective is to enable students to perform independent research in the field of computer systems for business process management.

Course outcome

Students will be introduced to the latest trends in the development of business process management systems. They will be enabled to recognize key problems in the development of such systems and to define the required activities related to their practical implementation.

Course content

Theory classes

- Basic concepts related to business process management systems
- Lifecycle of business process management systems
- Adaptive business process management systems
- Business process management systems and knowledge management systems
- Issues related to the development of business process management systems

Guided independent research

- Preparing students to independently research written literature, scientific journals and web portals in the field of business process management systems.

Recommended literature

1. Mathias Weske, **Business Process Management**, Concepts, Languages, Architectures, Springer
2. Marlon Dumas, Marcello la Rosa, Jan Mendling, Hajo A. Rejiers **Fundamentals of Business Process Management**
3. Selected scientific papers.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Classes are held in a consultative manner and through interactive cooperation with the advisor and the appointed supervisor. The supervisor introduces students to the course content directly. After being introduced to the course content, each student, in cooperation with the supervisor, chooses a topic for the project task and works on it. It is expected that the final result of the work on the project task is a manuscript, recommended for presentation at a scientific conference, regardless of its rank.

Knowledge assessment (maximum number of points 100)

Project task (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**CYBER-PHYSICAL ENGINEERING SYSTEMS**
Professor/professors:	Milan M. Zdravković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring new knowledge in the field of cyber-physical engineering systems and Internet of Things systems for the purpose of independent scientific research in this field.

Course outcome

Students acquire knowledge that enables them to independently research various domain problems in engineering sciences and propose conceptual solutions based on cyber-physical systems and the Internet of Things. Students are able to independently model cyber-physical systems using UML/SysML and UML/MARTE languages and/or other formalisms.

Course content

Theory classes

- Components of cyber-physical systems (CPS). Internet of Things architecture. Smart devices (sensor and actuator components, smartphones, Raspberry Pi platform), device virtualization, gateway devices, “large data” storage systems.
- Specification, modelling and design of cyber-physical systems using UML/SysML and UML/MARTE languages and other formalisms. Interoperability and semantic interoperability of cyber-physical systems. Semantic models – domain ontologies for the implementation of cyber-physical systems (ADACOR).
- Functions of open source Internet of Things platforms in a cloud (domain platforms, M2M connectivity, analytics, visualization, integrated development environments).
- Applicative protocols for communication inside cyber-physical systems (ReST, CoAP, MQTT, XMPP).
- Application of distributed architectures in the implementation of cyber-physical systems (agent-based architecture, blockchain).
- Possibilities and scenarios of application of cyber-physical systems in manufacturing (so-called smart factories), energy engineering, smart buildings, security, transport, communal activities.
- Cyber-physical system security (Security-by-design, Privacy-by-design, access control schemes).
- Regulatory aspects of the implementation of cyber-physical systems (connectivity, privacy, security, standards, ownership).
- Directions for further research in the field of cyber-physical engineering systems and Internet of Things: mass scaling (addressing, detection of devices in smart ecosystems, heterogeneity challenges), interoperability in CPS ecosystems, observation of knowledge in data (interpretation of data in real time, new reasoning techniques), reliability, multimodal interfaces (virtual and augmented reality).

Guided independent research

- Preparing students to perform independent analysis and synthesis of the literature and other sources of information on cyber-physical engineering systems. Independent analysis and preparation of project proposal concepts for funding within the European research area for relevant calls. Independent specification, modelling and design of cyber-physical engineering systems. Independent implementation of a simple CPS using open source software and hardware platforms.

Recommended literature

1. Раденковић, Б., Деспотовић-Зракић, М., Богдановић, З., Бараћ, Д., Лабус, А., Бојовић, Ж (2017). **Интернет интелигентних уређаја [Internet of intelligent devices]**. Факултет организационих наука
2. Friedenthal, S. (2011) **A Practical Guide to SysML: The Systems Modeling Language**. Morgan Kaufmann
3. Rowland, C., Goodman, E., Charlier, M., Light, A., Lui, A (2015) **Designing Connected Products**. O'Reilly
4. McEwen, A., Cassimally, H. (2013) **Designing the Internet of Things**. Wiley

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures and interactive work with students, demonstration of appropriate tools, guided independent research of students, term paper.

Knowledge assessment (maximum number of points 100)

Term paper (70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**MANUFACTURING OF BIOMEDICAL PRODUCTS**
Professor/professors:	Miodrag T. Manić, Jelena R. Milovanović
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Acquiring knowledge to analyse, design and manufacture medical devices and implants, with a special emphasis on prosthetic devices in skeletal prosthetics.

Course outcome

Knowledge of methods for the manufacture of medical devices and implants. Application of acquired knowledge to concrete problems in the dissertation and project work.

Course content

Theory classes

- Medical aids, bionics, prostheses, implants and osteo fixation materials.
- Lifecycle of medical devices and implants: preliminary concept, design and development, manufacturing, service and maintenance, end of use and recycling of devices.
- Legal and ethical standards in the manufacturing and application of medical devices and implants.
- Software systems for modelling, design and analysis of prosthetic devices.
- Materials for prosthetic devices, criteria for the selection and testing of materials. Biocompatible and biodegradable materials.
- Additive technology for manufacturing of implants and devices.
- Surface treatment and protection of prosthetic devices.
- Manufacturing techniques for customized prosthetic devices and implants.
- Biotribology, friction wear and lubrication of orthopaedic implants.
- Scaffold manufacturing.
- Controllable and intelligent medical devices.
- The algorithm for achieving the CE mark. European directives and national legislation.

Guided independent research

- A term paper in which students can apply the acquired knowledge to a real product.

Recommended literature

1. Ian Gibson, **Advanced Manufacturing Technology for Medical Applications: Reverse Engineering, Software Conversion and Rapid Prototyping**, John Wiley & Sons, 2006
2. R. Narayan, P. Calvert, **Computer Aided Biomanufacturing**, John Wiley & Sons, 2011
3. K. Torrin, **A Guide to Prosthesis, Including Its Background, Innovation and Development, Materials, and More**, Webster's Digital Services, 2012..
4. Chao Lin, **Biomedicine**, Publisher InTech, Published online 21, March 2012,
5. **Manufacturing guidelines for Partial foot prosthesis**, International Committee of the Red Cross, ICRC, Geneve, 2006

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Teaching by using multimedia tools, term papers.

Knowledge assessment (maximum number of points 100)

Term papers (2 x 35 points = 70 points) and oral exam (30 points).

Study programme:	***Mechanical Engineering***
Type and level of studies:	Doctoral Academic Studies
Course title:	**THERMAL COMFORT**
Professor/professors:	Mladen M. Stojiljković
Course status:	Study programme elective course
ECTS credits:	10
Requirements:	None

Course objective

Thermal comfort is one of the most influential elements of the condition and quality of living and working spaces. Therefore, it is very important to introduce students to the definition and determination, both experimentally and numerically, of thermal comfort parameters and indicators for the purpose of further training in the field of HVAC technology.

Course outcome

Students are able to determine the thermal comfort domain under the influence of subjective and objective comfort parameters and indicators, assess thermal environment, and measure and analyse microclimate parameters and thermal environment conditions.

Course content

Theory classes

- Introduction, basic concepts and definitions of thermal comfort as a condition of thermal environment.
  - Parameters influencing thermal comfort;
  - Ambient parameters (relative humidity, temperature, air velocity, mean radiant temperature);
  - Subjective parameters (metabolic intensity, Clo-value).
- Human body heat flux – defining all heat losses and gains of the human body heat balance.
  - Metabolic rate;
  - Heat loss by steam diffusion through the skin and sweat evaporation from the skin surface;
  - Heat loss by convection and evaporation in the respiratory tract;
  - Heat loss by heat transfer from the skin to the outer surface of the clothing;
  - Heat loss by convection and radiation from the surface of the clothed body, etc.
- Conditions of thermal comfort.
  - Thermal comfort equation – Fanger equation;
  - Te Diagrams of thermal comfort defining intercorrelations of thermal comfort parameters;
  - Thermal comfort indicators PMV, PPD and their mutual relations;
  - The impact of other factors on the scope of the thermal comfort equation application (ethnic, geographic, age, sex, body type, diet, asymmetric heating or cooling, hot or cold surface, paint, air pressure, etc.).
- Practical methods of thermal environment evaluation.
  - Defining PMV indicators;
  - Defining PPD indicators;
- Measuring methods of microclimate parameters.
  - Defining mean radiant temperature;
  - Radiative heat loss from the human body surface;
  - Determination of the angular factor (configuration factor) of the human-room system.
- Thermal environment condition analysis in terms of thermal comfort.

Guided independent research

- Preparing students to do research within their doctoral dissertation by writing a term paper directly correlated with the consideration of thermal comfort.

Recommended literature

1. Fanger P. Ole, **Thermal Comfort**, Analysis and Applications in Environmental Engineering, TU Copenhagen, 1970.
2. Fanger P. Ole, **Indoor Climate Course**, TU Copenhagen, spring 2003.
3. Awbi B. Hazim, **Ventilation in Buildings**, Clays Ltd., UK, 1991.

Number of active teaching classes	Lectures	3	Guided independent research	3

Teaching methods

Lectures, term papers.

Knowledge assessment (maximum number of points 100)

The final exam is taken in the form of an oral exam (30 points). The requirement for taking the exam is the defended independently written term paper (70 points).