University of Belgrade

Faculty of Mechanical Engineering

Course catalog

Master (M.Sc.) Academic Studies – Mechanical Engineering

Belgrade

2022.

TABLE OF CONTENTS

MFB

Aberration theory and image analysis

ID: MSc-1355
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal of a course Aberration theory and image analysis is to present all necessary theoretical and practical knowledge that is required for successful design of complex optical systems. The theoretical knowledge is obtained by studying various types of aberrations, the spot diagram, the point spread function, the optical transfer function and the diffraction. Emphases in aberration study are given on studying how aberrations appear and what are possible ways of correction aberrations. The practical knowledge is obtained through the analysis of various existing optical systems in the standard program for optical design.

learning outcomes
At the end of the course students will have practical knowledge of understanding and calculating aberrations and other image analysis techniques like the spot diagram, the point spread function, the optical transfer function.

theoretical teaching
1. Wavefront aberrations

2. Primary aberrations

3. Seidel aberrations

4. Chromatic aberrations

5. Calculation of aberrations

6. Spot diagram

7. Point spread function

8. Observation and measurement of aberrations

9. Fundamentals of radiometry and photometry

10. Diffraction

11. Resolution of optical systems

12. Optical transfer function

13. Aberrational tolerances

14. Tolerances of optical elements

practical teaching
1. Calculation and analysis of aberrations in various optical systems by standard program for lens design,

2. Calculation and analysis of spot diagrams in various optical systems by standard program for lens design,

3. Calculation and analysis of optical transfer functions in various optical systems by standard program for lens design,

4. Visit to Laboratory for quantum and nonlinear optics, Photonics Center, Institute of Physics, University of Belgrade and demosntration of various types of lasers (femtosecond laser system Coherent Mira 900 D, continuous pumping laser system Coherent Verdi V10),

5. Visit to Laboratory for holography, optical materials and photonic cristals, Photonics Center, Institute of Physics, University of Belgrade and demonstration of interferometric measurements in optics.

prerequisite
There is no obligatory prerequisites.

learning resources
1. Mahajan V.: Optical Imaging and Aberrations Part I Ray Geometrical Optics, SPIE Press, Bellingham, Washington USA, 1998.

2. Mahajan V.: Optical Imaging and Aberrations Part II Wave Diffraction Optics, SPIE Press, Bellingham, Washington USA, 2001.

3. Welford W.T.: Abberations of Optical Systems, Adam Hilger, Bristol UK, 1986.

4. Standard program for lens design

5. Laboratory for quantum and nonlinear optics and Laboratory for holography, optical materials and photonic cristals, Photonics Center, Institute of Physics, University of Belgrade.

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 2
laboratory exercises: 4
calculation tasks: 18
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30

project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Actuating Systems

ID: MSc-0751
responsible/holder professor: Miloš V. Marko
teaching professor/s: Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: MFB

goals
Acquisition of general and basic knowledge of the actuating systems.

To qualify students to understand the actuating systems, main components and principle of operation.

Training for further study.

learning outcomes
The knowledge gained will be used in engineering practice for initial design and selection the basic elements of various types of the actuating systems.

theoretical teaching
An overview of the actuating systems including the general overview of the various type of actuators. Classification of the actuators according to the type of transformation & movement and according to the possible applications is presented. Electro-pneumatic (EPA), electro-hydraulic (EHA) and electro-mechanical actuators (EMA) are discussed. General recommendations for design and testing, calculations and choosing of the components are included also.

Main Topics:

1. Electro-mechanical actuators (EMA) & Mechanical parts of EMA
2. Electric motors
3. Motor controller
4. Contol requirements, control system & stability
5. Electro-hydraulic actuators (EHA) – configuration, working medium, servo-valves
6. EHA – power sources, hydraulic motor design
7. EHA – mathematical modeling and synthesis of control system
8. Electro-pneumatic actuators (EPA) – configuration, mathematical modeling
9. Simulation technicue for the actuators
10. Testing & verification of the actuators
11. Some procedures in design of the actuators and quality assurance

practical teaching
1. Visiting to Component Maintenance Department of "JAT Tehnika - aircraft maintenance center" in Belgrade.
2. Visiting to Military Technical Institute - Servo Systems Laboratory in Belgrade.
3. Visiting to Department of Automatic Control of Faculty of Mechanical Engineering.
4. EMA presentation – office 136 [Faculty of Mechanical Engineering.

prerequisite
None

learning resources
Moodle (Modular Object-Oriented Dynamic Learning Environment , a free, open-source PHP web application for producing modular internet-based courses that support a modern social constructionist pedagogy).

Lectures, power point presentations, romm equipped with computers & software for design and simulations, handouts.

number of hours: 75

active teaching (theoretical): 40
lectures: 30
elaboration and examples (revision): 10

active teaching (practical): 20
auditory exercises: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 15
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 40
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 45
requirements to take the exam (number of points): 0

references
M.Milos, Actuating Systems, professor's handouts
W. Bolton: Mechatronics-Electronic Control Systems in Mechanical and Electrical Engineering – Pearson, 2012.

Advanced aerospace propulsion systems

ID: MSc-1350
responsible/holder professor: Ivanov D. Toni
teaching professor/s: Ivanov D. Toni
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: MFB

goals
The course is aimed at providing basic knowledge of the methods for aircraft/spacecraft propulsion and a more detailed understanding of modern aerospace propulsion systems. The main objective is to provide students with the practical capability of calculating thrust force and propulsion system performance analytically and using self-written numerical tools.

Students will acquire knowledge of the performance of individual propulsion system components as well as the integration of the propulsion system on the aircraft/spacecraft.

Additionally, students are going to be introduced to micro-propulsion systems as well as to novel aerospace materials and manufacturing methods.

learning outcomes
At the end of the semester, students would have acquired knowledge of the principles of aerospace propulsion and detailed knowledge of the aerothermodynamics behind airbreathing and rocket engines. This will allow understanding of the methods for performance analysis of real engines and their components. Students will acquire the necessary knowledge and practical skills about the numerical concepts and techniques of modelling and performance analysis with regards to the materials and manufacturing processes which will allow them to carry out preliminary designs of aerospace propulsion systems to meet specified requirements.

theoretical teaching
1. Introduction of aerospace propulsion systems and areas of application.

2. Fundamental equations of aerospace propulsion

3. Airbreathing propulsion systems.

4. Solid fuel propulsion systems.

5. Liquid fuel propulsion systems.

6. Hybrid propulsion systems.

7. Electric propulsion systems.

8. Micropropulsion systems.

9. Propellantless propulsion systems.

10. Aerospace materials and manufacturing methods.

practical teaching
Each topic is illustrated through accompanying practical examples, their analysis and discussion of the previously presented theory.

prerequisite
Basic knowledge of thermodynamics and gas dynamics is preferred but not required.

learning resources

Lecture notes and power point presentations.

Computer room with necessary software tools.

number of hours: 75

active teaching (theoretical): 42
lectures: 28
elaboration and examples (revision): 14

active teaching (practical): 19
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 4
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 14
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

George P. Suton, Oscar Biblarz, “Rocket Propulsion Elements (8th Ed)”, John Wiley and Sons Inc, 2010
Martin J.L. Turner, "Rocket and Spacecraft Propulsion, Principles, Practice and New Developments (3rd Ed)", Springer - Praxis, 2009
F.C. Campbell. "Manufacturing Technology for Aerospace Structural Materials", Elsevier Ltd., 2006

Advanced interior ballistics

ID: MSc-1405
responsible/holder professor: Jevtić T. Dejan
teaching professor/s: Jevtić T. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Introducing students to the basics of classic projectile propulsion. Study of fundamental processes that occur during firing in the gun barrel. Influence of characteristics of propellants on firing processes. Setting up a system of equations describing these processes and methods for solving the system. Design of propellant systems. Study of methods of solving the basic task of interior ballistics and ballistic design. The study of characteristics of special types of weapons. Consideration of methodology of interior ballistic tests.

learning outcomes
Student gets knowledge of principles and basic equations of the propulsion. Student is trained for the calculation of basic parameters of interior ballistics. Student acquires fundamentals for subsequent detailed study of various types of propulsion. Mastering the calculation of direct and indirect task of interior ballistics of various types of weapons, and the methodology of interior ballistic tests.

theoretical teaching
Introduction to interior ballistics.

Gun propellants and their characteristics.

Basic processes and laws during firing process.

Solution of the basic task of interior ballistics (task statement, analytical method of solving, propellant gas temperature calculation, tabular method of solving).

Ballistic design.

The solution of the task of internal ballistics for the combined (howitzer) charge.

Interior ballistics of recoilless weapons.

Interior ballistics of mortars.

Corrective formulas of interior ballistics.

Interior ballistic tests (objective, classification and measuring parameters). Interior ballistic test preparation. Pressure measurement. Measurement of gun muzzle velocity. Measuring of recoil system impulse.

practical teaching
Combustion of gunpowder. Examples of calculations

The main tasks of the interior ballistics. Energy balance during the firing. The basic equations of interior ballistics. Solving problems.

The basic equations of propulsion systems. Problems

Production of gunpowder.

Tabular method of solving the basic task of interior ballistics.

Interior ballistic design (Task of gun tube design. Interior ballistic characteristic of weapons.

General dependence of structural tube characteristics on charge conditions. Directive diagram and its analysis).

The solution of the task of interior ballistics for the combined (howitzer) charge.

Corrective formulas of interior ballistics. Selected examples.

prerequisite
No.

learning resources
number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Advanced missile guidance and control

ID: MSc-1155
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Acquiring knowledge in the field of missile guidance and control with the possibility of applications in the fields of research and development, designing, manufacturing, marketing, operational use and analysis of modern guided missiles. Mastering the methodology of the calculations of dynamic characteristics of guided missiles (maneuverability, stability, the natural frequency, etc.), autopilot synthesis and synthesis of different types of guidance laws.

learning outcomes
The student acquires general knowledge in the areas of analysis and synthesis system of guided missiles that enables participation and communication in work teams involved in the development of guided missiles. With the use of modern software tools developed in MATLAB and Simulink, are qualified for the trajectory calculation of guided missiles, aerodynamic transfer function calculation and the synthesis of the autopilot and the missile guidance system. It has acquires knowledge in the areas of testing of missile guidance system.

theoretical teaching
Introduction to the theory of guidance and control of the missiles (the basic principles of guidance and control). Analysis of dynamic characteristics of missiles and calculation of aerodynamic transfer functions. Requirements and methods of designing autopilots. Analyses and syntheses of proportional navigation, command to LOS guidance and different approaches for trajectory correction and trajectory guidance.

practical teaching
The practical realization of guided missiles (analyzed various construction solutions of guided missiles to review the role of guidance and control subsystem. The application of MATLAB and Simulink in design). Designing pitch, yaw and roll autopilots. Each student should solve project of guidance system for the given missile data.

prerequisite
None.

Passed exams (preferably): flight dynamics and aerodynamics of projectiles, Fundamentals of automatic control

learning resources
Cuk, D .: Lectures in course Missile guidance and control, Faculty of Mechanical Engineering, Belgrade, 2002 (handouts)

number of hours: 75

> **active teaching (theoretical):** 25
> lectures: 20
> elaboration and examples (revision): 5
>
> **active teaching (practical):** 35
> auditory exercises: 5

laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 45
requirements to take the exam (number of points): 0

references
P. Garnel: Guided Weapon Control System, Pergamon Press, New York, 1980.;
Danilo Ćuk: Design of Beam-Riding Laser Guidance System,MTI, 1998.
Danilo Ćuk: Theory of Homing Systems, Proportional Navigation,MTI, 1998.

Advanced Nuclear Reactors

ID: MSc-1409
responsible/holder professor: Stevanović D. Vladimir
teaching professor/s: Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Acquiring knowledge on principles and methods for development of advanced nuclear reactors with improved safety features and economics. An overview of research requirements within developments of advanced reactors.

learning outcomes
Ability to define topics and contents of research with the aim of designing advanced nuclear reactors. Application of a specific thermal-hydraulic method for a design of defined technical features of an advanced reactor.

theoretical teaching
An overview of nuclear reactor operational principles. Methods of nuclear reactor thermal-hydraulic design. Study and analyses of generation III, III+ and generation IV reactors. Features and merits of small modular reactors.

practical teaching
Application of a thermal-hydraulic method for the analysis and design of a specific nuclear reactor feature. Evaluation of advanced reactors design characteristics and improvements regarding improved safety features and economics of operation.

prerequisite
Passed exams in Thermodynamics, Fluid Mechanics, Higher Mathematics and the basic course in Nuclear Reactors at Bachelor or Master studies.

learning resources
Lecture notes, computer equipment, in-house and commercial computer codes for thermal-hydraulic analyses.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 15
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 10
> project design: 0
> consultations: 5
> discussion and workshop: 0
> research: 0
>
> **knowledge checks:** 15
> check and assessment of calculation tasks: 0
> check and assessment of lab reports: 0

check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

D. Bodansky, Nuclear Energy, Principles, Practises, and Prospects, Springer, 2004.
Tong, L.S., Principles of Design Improvements for Light Water Reactors, Hemisphere, 1988.
Saha, P., Issues and future direction of thermal-hydraulics research and development in nuclear power reactors, Nuclear Engineering and Design, 264 (2013), pp. 3-23
Klimov, A., Nuclear Physics and Nuclear Reactors, Mir Publishers, Moscow, 1981.
Knief, R.A., Nuclear Energy Technology, Hemisphere, 1981.

Advanced optical system design

ID: MSc-1309
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal of the course Advanced optical system design is to transfer practical knowledge in designing various optical systems. This means that students will learn from very beginning how to design various optical systems. The complexity of optical systems varies from simple ones with only one or two lenses to quite complex ones with up to ten lenses.

Each lecture will cover the design of one kind of the visual optical systems. The first part of lecture will give theoretical introduction and the second part of lecture will consist of interactive design and analysis of selected optical system in standard optical design program.

learning outcomes
At the end of the course students will have practical knowledge of designing all basic visual optical systems. This means that students can design various optical systems from the Wollaston landscape lens to the Petzval and the Double Gauss lens. Students will have necessary knowledge for designing various double mirror objectives like the Newton system, the Cassegrain system and the Gregory system.

theoretical teaching
1. Design of the best form lens
2. Design of the Wollaston landscape lens
3. Design of the cemented doublet
4. Design of the French landscape lens
5. Design of the separated doublet
6. Design of the finite separated doublet
7. Design of the Cooke triplet
8. Design of the Tessar lens
9. Design of the Petzval lens
10. Design of the Telephoto lens
11. Design of the Double Gauss lens
12. Design of the Schmidt system
13. Design of the Bouwers – Maksutov system
14. Design of the Newton two mirror system
15. Design of the Cassegrain two mirror system
16. Design of the Gregory two mirror system

practical teaching

1. Analysis of the best form lens in standard lens design program
2. Analysis of the Wollaston landscape lens in standard lens design program
3. Analysis of the cemented doublet in standard lens design program
4. Analysis of the French landscape lens in standard lens design program
5. Analysis of the separated doublet in standard lens design program
6. Analysis of the finite separated doublet in standard lens design program
7. Analysis of the Cooke triplet in standard lens design program
8. Analysis of the Tessar lens in standard lens design program
9. Analysis of the Petzval lens in standard lens design program
10. Analysis of the Telephoto lens in standard lens design program
11. Analysis of the Double Gauss lens in standard lens design program
12. Analysis of the Schmidt system in standard lens design program
13. Analysis of the Bouwers – Maksutov system in standard lens design program
14. Analysis of the Newton two mirror system in standard lens design program
15. Analysis of the Cassegrain two mirror system in standard lens design program
16. Analysis of the Gregory two mirror system in standard lens design program

prerequisite

There is no obligatory prerequisits.

Passed exam prefered:

- Introduction to optical system design
- Aberration theory and image analysis

learning resources

1. Fischer R.E., Tadic-Galeb B., Yoder P. R.: Optical System Design, Second Edition, McGraw Hill, New York, USA, 2008.
2. Smith W. J: Modern lens design, Second Edition, McGraw Hill, New York, USA, 2005.
3. Smith W. J: Modern optical Engineering, Forth Edition, McGraw Hill, New York, USA, 2008.
4. Standard program for lens design

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 20
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references

1. Fischer R.E., Tadic-Galeb B., Yoder P. R.: Optical System Design, Second Edition, McGraw Hill, New York, USA, 2008
2. Smith W. J: Modern lens design, Second Edition, McGraw Hill, New York, USA, 2005.
3. Smith W. J: Modern optical Engineering, Forth Edition, McGraw Hill, New York, USA, 2008.
4. Standard program for lens design

Airframe Structure Analysis

ID: MSc-0747
responsible/holder professor: Grbović M. Aleksandar
teaching professor/s: Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The Airframe Structure Analysis course aims to provide a clear introduction to the fundamental theory of structural analysis as applied to vehicles, aircraft, spacecraft and ships. The emphasis is on the application of fundamental concepts of structural analysis in everyday engineering practice. Coverage of elasticity, energy methods and virtual work set the stage for discussions of airworthiness/airframe loads and stress analysis of aircraft components.

learning outcomes
This course will give students an appreciation of the criteria used for selecting aircraft materials and designing aircraft structures. Students will get an overview of how structural loading and stress analysis influence the decisions upon aircraft shape and airworthiness. It is intended for students who need to be aware of the influence of aircraft materials and structural considerations in the development of aircraft design.

theoretical teaching
1. Basic Elasticity

2. Two-Dimensional Problems in Elasticity

3. Virtual Work and Energy Methods

4. Bending of Thin Plates

5. Euler Buckling of Columns

6. Buckling of Thin Plates

7. Loads on Structural Components of Aircraft. Materials used in design.

8. Airworthiness. Factors of Safety-Flight Envelope.

9. Airframe Loads; Aircraft Inertia Loads, Symmetric Maneuver Loads.

10. Bending of Open and Closed, Thin-Walled Beams.

11. Shear of Beams.

12. Torsion of Beams.

13. Combined Open and Closed Section Beams.

14. Wing Spars and Box Beams. Analysis.

15. Bending, shear and torsion of fuselage.

16. Bending, shear and torsion of wing.

practical teaching
During practical work students will learn different "manual" and computer based methods for solving typical aircraft structure analysis problems.

prerequisite
Fundamental background in higher mathematics is required. Students should have seen the following topics: derivatives, integration, matrices.

learning resources
Handouts, Virtual classroom (Moodle), Powerpoint presentations, Recommended literature and websites

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 5
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 20
final exam: 30
requirements to take the exam (number of points): 30

references
A. Grbovic, Handouts, Faculty of Mechanical Engineering, Belgrade, 2010.
An Introduction to Aircraft Structural Analysis, T. H. G. Megson, Elsevier, 2010.

Analytic Methods for Engineering Design

ID: MSc-0753
responsible/holder professor: Babić R. Bojan
teaching professor/s: Babić R. Bojan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: MFB

goals
Course aim is to scrutinize the design process in its entirety, from problem definition to conceptualization to embodiment and realization, in a discipline-independent framework, with the purpose of gaining insight into the process from the most general viewpoint.

learning outcomes
Apply mathematical, scientific and programming methods to find appropriate solutions to engineering problems. Advanced application of axiomatic design theory for design of products, manufacturing processes and manufacturing systems. Ability for structuring and decomposing designs in order to systematically apply design axioms. Advanced application of design software. Teamwork abilities.

theoretical teaching
Analytical methods in engineering design. Methodology of engineering design. Axiomatic approach in design. Basics of axiomatic design. Creativity and axiomatic design. Concept of domains. Problem definition and functional domains. Mapping process and its graphic interpretation. Design decomposition. Design for manufacturing. Information axiom and its implications. Manufacturing process planning and information content. Axiomatic design of products. Case studies of designs made by application of axiomatic design theory. Axiomatic design of manufacturing systems. Axiomatic approach to design of software. Ergonomics and axiomatic desing. Cost engineering in axiomatic design. Theory of inventive problem solving - TRIZ.

practical teaching
Examples of application of analytic design methods. Axiomatic design of products, processes and systems. Application of axiomatic design in manufacturing domain. Defining functional requirements for manufacturing system. Design for manufacturing, design of manufacturing processes and intelligent machines. Intelligent system for design of manufacturing systems. Project and consultations about project. Software packages for axiomatic design. Examples of making designs based on ergonomics. Discussions and workshops.

prerequisite
Defined by curriculum of study programme/module.

learning resources
(1) I-TRIZ Innovation WorkBench – a comprehensive software tool for inventive problem solving.

(2) I-TRIZ Ideation Brainstorming – a simplified tool for solving problems of light to medium complexity.

(3) Axiomatic design software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30

auditory exercises: 0
laboratory exercises: 22
calculation tasks: 0
seminar works: 8
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15

check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 15
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 35
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

B. Babic, FLEXY–INTELLIGENT EXPERT SYSTEM FOR FMS DESIGN,Intelligent Manufacturing Systems Series,Book 5, University of Belgrade, Faculty of Mechanical Engineering,1994,18.1
N. P. Suh, (1990) THE PRINCIPLES OF DESIGN, Oxford University Press, New York
G. J. Park, (2007) ANALYTIC METHODS FOR DESIGN PRACTICE, Springer Verlag, London

Applied optimization theory in optical system design

ID: MSc-0841
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal of a course Applied optimization theory in optical system design is to present necessary theory of the classical and the evolutionary optimization methods applied in the optical system design. Practical knowledge is obtained by applying several optimization methods in designing same optical system. This method enables to study good and weak points of various optimization methods and to choose the right optimization method for given optical system.

learning outcomes
At the end of the course students will have theoretical and practical knowledge of various classical and evolutionary optimization methods (dumped least squares, simulated annealing, genetic algorithms, evolutionary strategies) and their application in the optimization of optical systems.

theoretical teaching
1. Introduction to the optimization theory

2. Least squares optimization

3. Dumped least squares optimization

4. Spence's optimization

5. Grey's orthonormal optimization

6. Simulated annealing

7. Glatzel's adaptive optimization

8. Constrained optimization

9. Simple genetic algorithm

10. Adaptive steady state genetic algorithm

11. Two membered evolution strategy ES EVOL

12. Multimembered evolution strategy ES GRUP

13. Multimembered evolution strategy ES REKO

14. Multimembered evolution strategy ES KORR

practical teaching
1. Optimization of varous optical systems by using damped least squares in standard program for lens design,

2. Optimization of varous optical systems by using adaptive steady state genetic algorithm in standard program for lens design,

3. Optimization of varous optical systems by using two membered evolution strategy ES EVOL in standard program for lens design,

4. Optimization of varous optical systems by using multimembered evolution strategy ES GRUP in standard program for lens design,

5. Optimization of varous optical systems by using multimembered evolution strategy ES REKO in standard program for lens design,

6. Optimization of varous optical systems by using multimembered evolution strategy ES KORR in standard program for lens design.

prerequisite
There is no obligatory prerequisits.

Passed exam preferred:

- Introduction to optical system design
- Aberration theory and image analysis

learning resources
1. Vasiljević D.: Classical and Evolutionary algorithms in the optimization of optical systems, Kluwer Academic Publishers, Boston USA, 2002.

2. Nocedal J., Wright S. J.: Numerical optimization, Second edition, Springer, 2000.

3. Standard program for lens design.

4. Program for optimization of optical systems developed by Darko Vasiljevic.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 30

project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references

Assembly Automation

ID: MSc-0977
responsible/holder professor: Jakovljević B. Živana
teaching professor/s: Jakovljević B. Živana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Students acquire knowledge and develop practical skills referring to: the design and implementation of systems for automation of basic and auxiliary assembly processes, as well as automatic assembly systems as a whole; the design of products and processes for automatic assembly.

learning outcomes
Students obtain theoretical knowledge and practical skills in the design of automatic assembly systems, in particular for automation of transfer, feeding, orienting, part mating, fastening and joining within fixed and flexible assembly automation; master scientific methods for analysis, synthesis and design of assembly process sequences for automatic assembly; acquire knowledge and practical skills in design of products (parts and assemblies) for automatic assembly.

theoretical teaching
1. Introduction to assembly;

2. Structure of assembly system; basic, auxiliary and additional assembly processes;

3. Assembly sequence analysis; liaison diagrams; Bourjault method; datum flow chain;

4. Assembly transfer systems; continuous transfer; intermittent transfer; indexing mechanisms;

5. Automation of feeding and orienting; vibratory feeders; design of orienting systems;

6. Automation of fastening and joining processes;

7. Mating of compliantly supported rigid parts; gross and fine motions; quasi-static force model;

8. Vision systems in assembly automation; image analysis;

9. Design for automatic assembly;

10. Dimensioning and tolerancing for assembly; worst-case tolerancing; statistical tolerancing.

practical teaching
1. Auditory exercises: liaison sequence diagrams; quasi-static force model for mating of compliantly supported rigid parts; statistical and worst-case tolerancing.

2. Laboratory exercises:

- continuous and intermittent transfer systems;
- experimental identification of forces during mating of compliantly supported rigid parts;
- orienting of parts using vision system and image analysis.

3. Project: design of a system for automatic assembly of selected product

prerequisite
Defined by curriculum of study program

learning resources

1. Jakovljević Ž., Petrović P. B., Contact states recognition in robotized assembly, FME, Belgrade 2011 /In Serbian/

2. Jakovljević Ž., Assembly automation - Handouts, FME, Belgrade, 2015

3. "Pick and Place" electro-pneumatic modular robots with programmable controllers, Laboratory for manufacturing automation

4. Laboratory desk with pneumatic, electro-pneumatic and electric components and programmable controllers, Laboratory for manufacturing automation

5. Programming computers, Laboratory for manufacturing automation

6. Communication network of computers and programmable controllers, Laboratory for manufacturing automation

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 12
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references

Groover, M., Automation, Production Systems and Computer Integrated Manufacturing, Prentice-Hall, Inc. 1987.
Whitney, E., D., Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development, Oxford University Press, 2004, ISBN 0-19-515782-6

Boothroyd, G., Assembly Automation and Product Design, CRC Press, 2005, ISBN 978-1-57444-643-2
Boothroyd G., Dewhurst P., Knight W., Product Design for Manufacture and Assembly, Marcel Dekker, Inc., 2002, ISBN: 0-8247-0584-X

Combustion Physics

ID: MSc-1237
responsible/holder professor: Milivojević M. Aleksandar
teaching professor/s: Milivojević M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The aim of this subject is to provide students with the fundamental knowledge in combustion, the basic method of energy production, based on physical and chemical mechanisms of chemical reactions, transport phenomena, multiphase laminar and turbulent flows.

learning outcomes
After successful completion of this course, students should be able to:

- understand and improve combustion systems and environmental protection in practice.
- analyze modern combustion systems and environmental protection methods,
- validate combustion technologies in both existing and future energy transformation systems,
- apply the acquired knowledge in the areas of combustion science,
- work in research and development organizations.

theoretical teaching
1. Introduction. Elements of thermochemistry.
2. Chemical kinetics and equilibrium, Gibbs function.
3. Law of mass action, Arrhenius law, global and elementary reactions.
4. Transport phenomena.
5. Oxidation mechanisms. Combustion limits.
6. Laminar non premixed flames.
7. Laminar premixed flames.
8. Combustion in turbulent flows; Detonation,
9. Two phase flows combustion.
10. Formation of air pollutants from combustion: nitrogen oxides, carbon monoxide, sulfur oxides, soot and particulates.
11. Control of air pollutants.
12. Combustion in boundary layer flows; catalytic combustion; combustion in supersonic flows.

practical teaching
Practical tuition includes numerical analysis and examples of conservation of mass and energy laws regarding combustion and emissions. Experimental research includes non premixed and premixed flame characterization. Measurements of flue gas emission components will be performed in a purpose built test stand. A student will theoretically and numerically solve a problem in combustion.

prerequisite
Thermodynamics B exam passed

learning resources
The subject Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 24
elaboration and examples (revision): 6

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 5
seminar works: 5
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 10
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Kuo, K.K; Principles of Combustion, John Wiley & Sons, 1986.
Williams, F.A.: Combustion Theory (second edition) Addison-Wesley Publishing Company, 1985.

Computer Aided Design

ID: MSc-0733
responsible/holder professor: Grbović M. Aleksandar
teaching professor/s: Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The Computer Aided Design course aims to provide candidates with comprehensive 3D-CAD skills, as well as a detailed understanding of the main steps and design activities involved in the mechanical design process.

The Computer Aided Design course will provide some 'in-depth' guidance for students who want to learn methods for creation of complex 3D parts and assemblies, as well as generation of accurate CAD drawings which should define students´ design work.

During the course, the students will be trained using CATIA v5 software, and will learn the following modules in detail: Part Design, Drafting and Assembly.

learning outcomes
Computer Aided Design is a course for students who wish to acquire a comprehensive advanced 3D-CAD skills and a recognised qualification that can provide the basis for professional development in a mechanical design related field.

By completing this course, the students will be able to create simple and complex mechanical parts and assemblies within CATIA v5 environment, as well as precise drawings of designed parts/assemblies with all necessary dimensions and views.

At the end of the course, the students will also be able to prepare their 3D models for further work (i.e. finite element analysis of parts and assemblies or tool design) and will have enough skills to understand advanced courses in CAD design (for example, surface design and sheet metal design).

theoretical teaching
Introduction to Part Design & Sketcher:

Part Design Screen; Pull-down Menus; Toolbars in Part Design; Part Design Workbench; Sketcher Screen; Sketcher changes to bottom toolbar; Sketcher Workbench; Creating a new part with a new sketch

Creating basic shapes:

Rectangle, Oriented Rectangle, Parallelogram, Elongated Slot, Elongated Curved Slot, Keyhole, Hexagon, Circle, Circle through 3 points, Circle with Cartesian coordinates, Circle tangent to 3 elements, Arc through 3 points, Arc through 3 points using limits, Arc, Spline, Connect Curve, Ellipse, Parabola, Hyperbola, Conic, Line, Unlimited Line, Bi-tangent Line, Bisect Line, Axis, Point, Point using coordinates, Equidistant points, Intersection Point, Projection Point.

Profile options:

Constraints, Modifications of Sketch, Pad, Pocket, Shaft, Groove, Hole.

Creating and modifying parts:

Slot, Stiffener, Modifications to Shapes, Fillet, Chamfer, Draft Angle, Shell,

Thickness, Modifying values, Interfacing with Sketcher, Patterns, Multisection Solid

Introduction to Drafting:

Views generation, Set the angle projection, Set the fillet generation, Additional views, Offset section view, Offset section cut, Detailed drafting.

Assembly Design Fundamentals: Assembling Components, Positioning Components, Coincidence Icon, Contact Icon,Offset Icon, Fix Icon, Fix Together Icon, Analysing the assembly, Editing the assembly, Working with components, Creating the structure by inserting components, Positioning the components CATIA Parameters and Formulas: Connecting CATIA with Excel; Design Tablec.

practical teaching
All topics previously mentioned in theoretical section will be practiced on computers with installed CATIA v5 software. Every icon (option) and methods of design will be demonstrated by lecturer and students will repeat the same steps in order to acquire skills necessary to pass the final exam.

prerequisite
No previous CAD experience or skills are required although it would be an advantage.

learning resources
Handouts, Virtual classroom (Moodle), Powerpoint presentations, Computers with CATIA v5 software, Educational movies, Recommended literature and websites

number of hours: 75

active teaching (theoretical): 15
lectures: 10
elaboration and examples (revision): 5

active teaching (practical): 45
auditory exercises: 5
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 8
colloquium, with assessment: 3
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 50

references

A. Grbovic: Handouts, Faculty of Mechanical Engineering, Belgrade 2010.
Catia V5 Workbook: Release 14; Richard Cozzens, SDC Publications, 2006.

Control and Testing

ID: MSc-0772
responsible/holder professor: Ristanović R. Milan
teaching professor/s: Ristanović R. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Acquiring knowledge and deepening the theory of linear control systems.

Training for the implementation and testing of the acquired knowledge to concrete physical systems and processes.

learning outcomes
The knowledge gained is used in engineering practice for analysis, synthesis and verification of dynamic properties of the system.

theoretical teaching
P, PI, PD and PID control. Setting the PID controller. Integrator windup. Commercial regulators. PWM control. The analysis of state space systems. Models in state space: controllable, observable and diagonal canonical form. State space model transformation. The concept of controllability. Output controlability. The concept of observability. Stabilization by state feedback. The influence of state feedback on controllability and observability properties. Phase portrait. Lyapunov concept of stability. Properties of the system stability. The concept of controllability and observability. Overall frequency stability criteria. Introduction to the robustness of the system.

practical teaching
Analysis of the system through software tools MATLAB and Simulink. Experimental Determination of the system transfer function. Experimental setup controller.

prerequisite
Basic computer knowledge founded on PCs platforms. Бasic knowledge of higher education mathematics. Basic knowledge of linear systems theory.

learning resources
• Literature on the website http://au.mas.bg.ac.rs/el - Moodle

• Licensed Software in the possession of the Faculty.

• Freeware software.

• PCs.

• Laboratory of automatic control

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 5
seminar works: 0

project design: 0
consultations: 0
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 2
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 5
calculation tasks: 15
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Karl Johan Aström, Richard M. Murray, Feedback Systems, PRINCETON UNIVERSITY PRESS, New Jersey, 2008
Aström K., Hagglund, T., PID Controllers: Theory, Design, and Tuning, Instrument Society of America, Research Triangle Park, NC, 1995.
Nise N.S. Control Systems Engineering, John Wiley & Sons (Asia), 2011.
Dorf R.C., Bishop R.H., Modern Control Systems, Prentice Hall, NJ, 2008.
Franklin G.F., Powell J.D., Emami-Naeini A. Feedback Control of Dynamic Systems, Prentice Hall, NJ, 2009.

Design and Analysis of Composite Structures

ID: MSc-1307
responsible/holder professor: Dinulović R. Mirko
teaching professor/s: Dinulović R. Mirko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: MFB

goals

1. introduction to modern approach in stress analysis of composite material structures on aircraft, it's application to practical problems solutions as well as experimental methods applied to structural verifification of composite structures.

2.Introduction to specifics of thin walled structures and application of composite materials for these structures.

3.Introduction to computer simualtion and stress analysis of composite structures on aircrafts.

learning outcomes

1.Stress analysis of composite structures, micro-mechanics and Lamination theory

2. introduction to modern approach in stress analysis of composite material structures on aircraft, it's application to practical problems solutions as well as experimental methods applied to structural verification of composite structures.

3. Thin walled structures and application of composite materials.

4.Computer simulation and stress analysis of composite structures on aircrafts. (static and dynamic analysis) using Nastran and Ansys.

5. Introduction to Aeroelasicity of composite lifting surfacess

theoretical teaching

Basic Definitions. Polymer Matrix and fiber characteristics. Prepregs. Fabrication processes. Autoclave polymerization. Characteristics of composite materials. Elastic stres-strain behavor of composite materials modeling. Plane stress. Principal stresses, principal deformations. Temperatre deformations. Deformations in respect to humidity. Failure Criteria applicable to composite media. Kirchoff and Midlin plate theories. Effective mechanical characteristics of laminates. Composite Beams. Interlaminar stresses. Composite buckling. Delamination, structural analysis of composte material constructuctions using finite element method.

practical teaching

In the practical part of the course, stress-strain theory applicable to composite media is demonstrated. Real practical problems are analyzed. Practical work is carried out using computers and finite element analysis software for composite materials structures. Students are provided with all necessary materials in the form of lecture notes andbooks

prerequisite

Recommendation: Theory of elasticity, Strucural analysis of aircraft structures

learning resources

Course notes in electronic form, media materials, computer simulation models available after class, internet resources.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 50
final exam: 30
requirements to take the exam (number of points): 20

references

Design of logistic and warehouse systems

ID: MSc-1349
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Achieving competency and academic skills in the process of industrial system design. Special emphasis is focused on development of creative skills and overwhelm with specific practical skills needed for professional practice using operational research methods, procedures of analysis and synthesis for obtaining final goal which is optimal practical solution.

learning outcomes
Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of solutions in design process based on knowledge applying in practice using professional ethics as well as development of crucial and self-critical thinking and approach.

theoretical teaching
Logistic system in industrial environment (connection of production system with transport system, management of demand and purchase and warehouse system). Design system documentation (fusibility study, conceptual solution, conceptual design, tender documentation, main technological-mechanical project, other main projects, final contractor project and project of carried out state). Previous analysis needed for system design (general conditions for urban planning, logistics and transport connections, energetic potential). Design process procedure. Project realisation and generation of results.

practical teaching
Audit lessons (Introduction in design process for defined logistic-distribution system. Activity analysis for forming conceptual solution and conceptual design, activities connected with choosing of technological and other equipment, activities on forming main technological-mechanical project and final contractor project).

Project workmanship (Workmanship of the logistic-distribution system project. Defining of necessary parameters and surroundings for the given system design. Defining of needed system capacities. Forming of assignments for the other projects. Realisation of main technological-mechanical project).

prerequisite
There is no special conditions needed for course attending

learning resources
1. Bugaric, U., Petrovic, D.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011. (in print)

3. Bugaric, U.: Methodology for analysis of single position machines work, Foundation Andrejevic, Belgrade, 2003.

4. Zrnić, Đ., Petrović, D.: Factory design – assortment of solved examples, Faculty of Mechanical engineering Belgrade, Belgrade, 1990.

5. Zrnić, Đ., Petrović, D.: Stochastic process in transport, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.

6. Practical instruction in industrial environment.

7. Personal computers.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 5
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
consultations: 0
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 3
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 30

references
Asimow, M.: Introduction to Design, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
Hall, A. D.: A methodology for systems engineering, Van Nostrand, Princeton, New Jersey, 1962.
Kleinrock, L.: Queueing Systems, Volume I: Theory, John Wiley & Sons, New York, 1975.
Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.

Digital image processing

ID: MSc-1154
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The course Digital Image Processing is practical course of the image analysis and processing. This means that students will learn from very beginning how to design various useful procedures and algorithms in: Photometry and Colorimetry, Image Sampling and Reconstruction, Discrete Image Mathematical Characterization, Superposition and Convolution, Geometrical Image Modification, Morphological Image Processing, Image Segmentation and Two-Dimensional Fourier Transform in image processing, Object Extraction and Detection, Texture and Pattern Matching and Detection of Geometric Elements.

learning outcomes
At the end of the course students will have gained practical knowledge necessary of understanding, design and use different types of algorithms in image analysis and processing.

theoretical teaching
1. Perception, photometry and colorimetry
2. Image sampling and noise
3. Cameras
4. Image algebra
5. Image enhancement techniques
6. Edge detection and boundary finding techniques
7. Thresholding techniques
8. Thinning and skeletonizing
9. Connected component algorithms
10. Morphological transforms and techniques
11. Linear image transforms
12. Pattern matching and shape detection
13. Image features and descriptors
14. Geometric image transformations

practical teaching
1. Development of algorithms for camera calibration
2. Development of algorithms for image enhancement techniques
3. Development of algorithms for object detection
4. Development of algorithms for linear image transforms
5. Development of algorithms for geometric image transformations
6. Development of algorithms for texture and pattern matching

prerequisite
There is no obligatory prerequisites.

learning resources

1. I. T. Young, J. J. Gerbrands, L. J. van Vliet: Fundamentals of Image Processing, Delft University of Technology, Netherlands, 1998.
2. Gerhard X. Ritter, Joseph N. Wilson: Handbook of Computer Vision Algorithms in Image Algebra, CRC Press, Boca Raton, USA, 2000.
3. S. Mann: Intelligent image processing, Wiley, USA, 2002.
4. OpenCV Manual, Intel, USA, 2010.
5. Standard programs for image processing (ImageJ, GIMP, ...)
6. Digital Image Processing (program for testing of algorithms) developed by Z. Nikolić.

number of hours: 75

active teaching (theoretical): 30
lectures: 15
elaboration and examples (revision): 15

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 0
calculation tasks: 12
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Discrete Event Simulation

ID: MSc-0775
responsible/holder professor: Babić R. Bojan
teaching professor/s: Babić R. Bojan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The aim of the course is to develop student's ability to model and analyze real system using discrete event simulation along with application of models, analysis of simulation results and comparison of alternative solutions.

learning outcomes
After the course the students will understand the power, characteristics and limitations of discrete event simulation and how it is applicable for analyses and development of manufacturing and other discrete systems. Students' abilities to implement the model in a computer system will be developed. Also students will be able to verify the model built, to evaluate and analyze the model output, to compare alternatives and to make appropriate suggestions for the real system.

theoretical teaching
Introduction to discrete event simulation. What is simulation, when it is applicable to use simulation, classification of models, types of simulation, steps in simulation study, advantages/disadvantages of simulation study. Concept of discrete event simulation, list processing. Simulation package AnyLogic. Application of simulation. Verification and evaluation of simulation models, analysis of output data, comparison of alternative designs of systems. Simulation of manufacturing systems.

practical teaching
General principles and simulation examples. Simulation of single-chanel systems, event handling. Introdution to softwares for modelling and analysis of real systems based on discrete event simulation (lab work).

prerequisite
Defined by curriculum of study programme/module.

learning resources
(1) B. Babic, Handouts, University of Belgrade, Faculty of Mechanical Engineering, 2011, 18.1

(2) B. Babic, Electronic classrom for distance learning (http://147.91.26.15/moodle/), University of Belgrade, Faculty of Mechanical Engineering, 2011, 18.13

(3) AnyLogic simulation software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 22
calculation tasks: 0
seminar works: 8
project design: 0

consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 15
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 35
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

J. Banks, J. S. Carson, B. L. Nelson and D. M. Nicol (2005), DISCRETE EVENT SYSTEM SIMULATION, 4th Ed., Pearson Education International Series.

Dynamics of Structures

ID: MSc-0757
responsible/holder professor: Grbović M. Aleksandar
teaching professor/s: Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The Dynamics of Structures course aims to provide candidates with a detailed understanding of methods of analysis of aircraft structures exposed to loads caused by flight maneuvers, gust or turbulence. Influences of structure elasticity on static and dynamic stability of the aircraft will also be considered.

learning outcomes
To provide a strong theoretical base for analysis and evaluation of aircraft structures subjected to dynamic loading.

theoretical teaching
1. Vibration of multiple degree of freedom systems
2. Time domain solution
3. Frequency domain solution
4. The homogeneous and the particular solution for forced vibrations with damping.
5. Generalized equations of motion – matrix approach
6. Whole aircraft 'free-free' modes
7. Effect of wing flexibility on lift distribution
8. Divergence and control effectiveness
9. Introduction to unsteady aerodynamics
10. Flutter
11. Fatigue of structures
12. Ground vibration tests preparation.
13. Fatigue tests preparation.
14. Workshops and practical work.

practical teaching
During the practical work, students will learn how to solve typical dynamics of structure problems using both, modern numerical methods (FEM, BEM, XFEM) and classical (´manual´) approach. Student will also conduct several laboratory experiments (fatigue testing of aircraft spar, vibration testing of fuselage bulkhead, etc.) and will learn how to produce lab reports in the form required by the industry.

prerequisite
Fundamental background in aircraft structure analysis is required. Students should have seen the following topics: matrices, vectors, linear algebra.

learning resources
Handouts, Virtual classroom (Moodle), Powerpoint presentations, Recommended literature and websites

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 35
auditory exercises: 20
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 40
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
A. Grbovic, Handouts, Faculty of Mechanical Engineering, Belgrade, 2011.
Dynamics of Smart Structures, Ranjan Vepa, John Wiley And Sons Ltd
Structural Dynamics: Theory and Applications, Addison-Wesley, Tedesco.

Electric aircraft propulsion

ID: MSc-1351
responsible/holder professor: Ivanov D. Toni
teaching professor/s: Ivanov D. Toni
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: MFB

goals
Electric propulsion systems are the future of aircraft propulsion, hence the goal of this course is to provide students with knowledge of the working principles behind this kind of propulsion.

Students are going to be introduced to the theoretical background as well as the practical implications behind the design, analysis and implementation of this kind of propulsion systems.

learning outcomes
Upon successful completion of the course, students would have acquired knowledge of the principles behind electric aircraft propulsion as well as the competence to perform performance analyses of such systems. Students will also be equipped with the practical skills necessary to perform component parameter estimation, design experiments and analyze obtained results.

theoretical teaching
The theoretical part of the Course will cover the following topics:

1. Introduction to aircraft propulsion.

2. Introduction to electric aircraft propulsion systems.

3. Propeller design and analysis.

4. Ducted fan design and analysis.

5. Permanent magnet electric motors.

6. Electric motor drivers and control.

7. Energy storage for electric propulsion systems.

8. Distributed electric propulsion systems.

9. Hybrid electric propulsion systems.

practical teaching
The practical part of the Course will include:

1. Numerical examples covering the theory part.

2. Parameter identification and analysis of the electric propulsion system components.

3. Experimental investigation of the static thrust of a small UAV electric propulsion system.

prerequisite
Basic knowledge of aerodynamics and electronics is preferred but not required.

learning resources
Lecture notes and power point presentations.

Computer room with necessary software tools.

Static thrust test stand for small electric aircraft propulsion systems.

number of hours: 75

active teaching (theoretical): 40
lectures: 30
elaboration and examples (revision): 10

active teaching (practical): 25
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 0
seminar works: 3
project design: 0
consultations: 0
discussion and workshop: 2
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 40
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Fatigue of Thin Walled Structures

ID: MSc-0769
responsible/holder professor: Grbović M. Aleksandar
teaching professor/s: Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The main aims of Fatigue of Thin Walled Structures course are:

1. to emphasize the importance of fatigue failure problems in aircraft structures,

2. to indicate how this phenomenon can be analyzed and

3. how detailed analysis can contribute to the designing of fatigue resistant structures which will prevent structural fatigue problems in service.

learning outcomes
Knowledge of the fatigue mechanism in the material and how it can be affected by a large variety of practical conditions is the most important outcome of this course. Also, the students will gain basic knowledge about so-called “design against fatigue”. This approach includes not only the overall concept of the structure with related safety and economic aspects, but also questions on detail design, material surface quality, and joints used in aircraft structures. At the end of the course, the student should be skilled enough to try to predict (with good accuracy) the fatigue performance of aircraft structure, fatigue limits, fatigue lives until crack initiation and the remaining life covered by crack growth until final failure.

theoretical teaching
1. Fatigue as a Phenomenon in the Material.

2. Stress Concentration at Notches.

3. Residual Stress.

4. Stress Intensity Factors of Cracks.

5. Fatigue Properties of Materials. Fatigue under Constant-Amplitude Loading.

6. Fatigue Crack Growth. Methods of Analysis and Predictions.

7. Load Spectra and Fatigue under Variable-Amplitude Loading.

8. Fatigue Crack Growth under Variable-Amplitude Loading.

9. Fatigue Tests and Scatter. Experimental Analysis of Specimen.

10. Fatigue of Aircraft Structures.

11. Crack Growth Predictions for Aircraft Structures Under Constant and Variable Loading.

12. The Use of Finite Element Method (FEM) in Fatigue Analysis.

13. The Use of Extended Finite Element Method (XFEM) in Fatigue Analysis.

14. Evaluation of Prediction Methods for Fatigue Crack Growth in Aircraft Structures Under Constant and VA-load Histories.

practical teaching
Practical work will cover analysis of different fatigue specimens and crack growth in aircraft spars under constant and variable amplitude loading. Results obtained in experiments will be compared to numerical values obtained using FEM and XFEM.

prerequisite
No special requirements

learning resources
Handouts, Virtual classroom (Moodle), Powerpoint presentations, Recommended literature and websites, Ansys software, Abaqus software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 5
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 20
final exam: 30
requirements to take the exam (number of points): 30

references
A. Grbovic, Handouts, Faculty of Mechanical Engineering, Belgrade, 2012.
Jaap Schijve, Fatigue of Structures and Materials, 2009 Springer.
Fatigue Design Methods, Boeing Coorp.
Soheil Mohammadi, EXTENDED FINITE ELEMENT METHOD, 2008.

Fiber optical data transfer

ID: MSc-0844
responsible/holder professor: Vasić-Milovanović I. Aleksandra
teaching professor/s: Vasić-Milovanović I. Aleksandra
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal of the course Fiber optical data transfer is to provide basic knowledge of fiber optics, together with the methodology of fiber optical communication technology and mechanical and optical performance evaluation. This course also covers basic principles of fiber optic bobbin design, single mode fiber optic, measurement techniques, classification and characterization. In addition to the above, there is also an introduction of specific optical fibers that are part of fiber optical sensor systems (transmitters and receivers).

learning outcomes
At the end of the course students will have practical knowledge of fiber optic technology and its various applications in data transfer, together with knowledge of fiber optics bobbin production and principles of testing and verification.

theoretical teaching
Theoretical teaching

1. Basic principles of fiber optics
2. Classification and types of fiber optic cables
3. Fiber optic cable preparation
4. Fiber optic cable termination
5. Mechanical splicing
6. Fiber cable design and routing
7. Fiber optic bobbin design principles
8. Fiber optical sensors
9. Measurement techniques and systems
10. Fiber optical transmitters and receivers

practical teaching
Practical teaching

1. Calculation of fiber optic signal distribution
2. Fiber optic bobbin calculation and design
3. Fiber optical data transfer in various applications – laboratory exercises
4. Fiber optic testing (OTDR, Power Meter) - laboratory exercises
5. Fiber optic bobbin testing - laboratory exercises.

prerequisite
There is no obligatory prerequisits.

learning resources

1. Govind P. Agrawal: Fiber-optic Communication Systems, 4th edition, Wiley&Sons, Inc. Publication, USA, 2010.
2. John Crisp: Introduction to Fiber Optics, 2nd edition, Newnes, Linacre House, Jordan Hill, Oxford, UK, 2001.
3. Mohammad Azadeh: Fiber Optics Engineering, Springer, 2009.
4. Harry J.R.Dutton: Understanding Optical Communications, IBM, USA, 1998.

Laboratories

1. Institute of Physics
2. Faculty of Mechanical engineering – Laboratory for guidance and control

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 4
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Govind P. Agrawal: Fiber-optic Communication Systems, 4th edition, Wiley&Sons, Inc. Publication, USA, 2010

John Crisp: Introduction to Fiber Optics, 2nd edition, Newnes, Linacre House, Jordan Hill, Oxford, UK, 2001

Mohammad Azadeh: Fiber Optics Engineering, Springer, 2009.

Harry J.R.Dutton: Understanding Optical Communications, IBM, USA, 1998.

Fundamentals of guided missiles navigation systems

ID: MSc-1157
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
This course is based on the acquisition of knowledge of navigation systems, primarily inertial navigation and a global positioning system, with the goal that the information derived from the navigation systems can be used trajectory guidance or the path correction.

learning outcomes
After this course, the student is trained for independent work in the field of navigation systems and acquires the necessary knowledge to participate in new development projects in this field.

theoretical teaching
Basics of inertial navigation. Historical development of inertial navigation and strapdown INS. Coordinate frames. Kinematic Euler equation and algorithms of solving (Euler's angles, quaternions, Hamilton's parameters, Rodriges's theorem). Gyroscopes and accelerometers. Calibration of inertial units, testing and error correction. The basics of the global positioning system. Integrated navigation systems.

practical teaching
INS algorithms. Influence of sensor errors on inertial navigation. Calibration algorithms. Algorithms of integrated navigation systems.

prerequisite
none

learning resources
Titterton, D.H. and Weston, J.L., ”Strapdown Inertial Navigation Technology – 2nd edition”, IEE Radar, Sonar, Navigation and Avionic Series 17, ISPB 0-86341-358-7, 2004

Savage, P.G., ”Strapdown Inertial Navigation Integration Algorithm Design Part 1: Attitude Algorithms”, Journal of Guidance, Control, and Dynamics, Vol. 21, No. 1, pp. 19-28, Jan.-Feb. 1998

Savage, P.G., ”Strapdown Inertial Navigation Integration Algorithm Design Part 2: Velocity and Position Algorithms”, Journal of Guidance, Control, and Dynamics, Vol. 21, No. 2, pp. 208-221, Mar.-Apr. 1998

Salychev, O., “Inertial Systems in Navigation and Geophysics”, Bauman MSTU Press, ISBN 5-7038-1346-8, MOSCOW 1998

Salychev, O., “Applied Inertial Navigation: Problems and Solutions”, Bauman MSTU Press, ISBN 5-7038-2395-1, MOSCOW 2004

number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 35
auditory exercises: 5
laboratory exercises: 5

calculation tasks: 10
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 45
requirements to take the exam (number of points): 0

references

Titterton, D.H. and Weston, J.L., ”Strapdown Inertial Navigation Technology – 2nd edition”, IEE Radar, Sonar, Navigation and Avionic Series 17, ISPB 0-86341-358-7, 2004
Salychev, O., “Inertial Systems in Navigation and Geophysics”, Bauman MSTU Press, ISBN 5-7038-1346-8, MOSCOW 1998
Salychev, O., “Applied Inertial Navigation: Problems and Solutions”, Bauman MSTU Press, ISBN 5-7038-2395-1, MOSCOW 2004

Gas dynamics and CFD

ID: MSc-1159
responsible/holder professor: Simonović M. Aleksandar
teaching professor/s: Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: MFB

goals
Education of students to apply compressible flow theory to typical aerodynamic problems. Determination of flow parameters based on quasi one-dimensional theory. To be able to apply theory of characteristics to computation of supersonic flow in nozzles and diffusers

learning outcomes
Application of compressible flow equations for determination of flow parameters through normal and oblique shock waves. Application of Prandtl Meyer expansion theory. Application of method of characteristics on supersonic flows. Analysis of flow with shock waves.

theoretical teaching
Basic thermodynamics. Stationary flow through stream-tube. Normal and oblique shock wave. Expansion flow theory. Unsteady compressible one-dimensional flows. Shock waves. Method of characteristics.

practical teaching
Theoretical concepts are illustrated by computational examples. Instead of tables and charts small Matlab programs and Maxima programs are developed and used

prerequisite

-

learning resources
Classroom, projector, laptop.

number of hours: 75

active teaching (theoretical): 50
lectures: 50
elaboration and examples (revision): 0

active teaching (practical): 20
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0

check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 60
final exam: 10
requirements to take the exam (number of points): 35

references

G. Emanuel, "Gasdynamics: Theory and Applications", AIAA, New York, 1986

J. D. Anderson, Jr., "Modern Compressible FLow", McGraw-Hill Book Company, New York, 1982.

A. Shapiro, "The Dynamics and Thermodynamics of Compressible Fluid FLow", The Ronald Press Co., New York, 1953.

Industrial logistic

ID: MSc-1348
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Achieving competency and academic skills in the process of industrial system design. Special emphasis is focused on development of creative skills and overwhelm with specific practical skills needed for professional practice using operational research methods, procedures of analysis and synthesis for obtaining final goal which is optimal practical solution.

learning outcomes
Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of solutions in design process based on knowledge applying in practice using professional ethics as well as development of crucial and self-critical thinking and approach.

theoretical teaching
Logistic system in industrial environment (role of logistic system in industry, functions which system must achieved and its benefit for industry). Elements of logistic system (production based on end user demand, distribution and warehouse systems). Basic sub-systems of logistic system (production with defined capacity, transport with defined technology and distribution warehouse system). Place and role of the warehouse in logistic system. Application and effects of application of logistic systems in industry (territory coverage with defining location of production and end user, reduction of transport and storage costs and increase of flexibility towards end user).

practical teaching
Audit lessons (Introduction in design process for defined logistic system – defining elements of logistic system and basic sub-systems for chosen logistic system. Introduction in warehouse design of palletized goods – defining of: reception area, main warehouse, distribution – order picking, shipping and warehouse management system).

Project workmanship (Determining of the optimal location of the logistic system in macro surrounding – positioning of warehouse regarding to production and end user as a function of transport system. Project of warehouse for palletized goods - defining of: packing and capacity, work technology, layout, reception and shipping and warehouse management system).

prerequisite
There is no special conditions needed for course attending

learning resources
1. Bugaric, U., Petrovic, D.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011. (in print)

3. Zrnić, Đ., Petrović, D.: Factory design – assortment of solved examples, Faculty of Mechanical engineering Belgrade, Belgrade, 1990.

4. Zrnić, Đ., Petrović, D.: Stochastic process in transport, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.

5. Bloomberg, D. J., LeMay, S. B., Hanna, J. B.: Logistics, Prentice Hall, New York, 2002.

6. Practical instruction in industrial environment.

7. Personal computers.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 5
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 10
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 30
requirements to take the exam (number of points): 30

references
Asimow, M.: Introduction to Design, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
Hall, A. D.: A methodology for systems engineering, Van Nostrand, Princeton, New Jersey, 1962.
Kleinrock, L.: Queueing Systems, Volume I: Theory, John Wiley & Sons, New York, 1975.
Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.

Infrared detectors

ID: MSc-1310
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The course Infrared Detectors covers theoretical and practical knowledge regarding principles of operation, design, manufacturing technology and application of infrared photodetectors for night vision/thermal imaging.

learning outcomes
At the end of the course students will have gained practical knowledge necessary to design and use different types of photodetectors for thermal imaging, including mercury cadmium telluride photovoltaic and photoconductive devices.

theoretical teaching
1. Elements of radiometry and photometry
2. Optical properties of systems
3. Fundamental performance of infrared photodetectors
4. Classification of infrared photodetectors
5. Figures of merit
6. Photon management in detectors
7. Noise management
8. Thermal detectors: bolometers, thermopiles and pyroelectric devices
9. Semiconductor (photon) detectors
10. Detection in (3-5) micrometer range: indium antimonide
11. Mercury cadmium telluride PV and PC detectors
12. Design and fabrication of mercury cadmium telluride devices
13. QWIP and QDIP devices
14. Focal plane arrays

practical teaching
1. Calculation of figures of merit of intrinsic semiconductor detector for night vision
2. Calculation of composition profiles for epitaxial mercury cadmium telluride
3. Design of uncooled mercury cadmium telluride detector

prerequisite
There is no obligatory prerequisites.

Passed exam preferred:

- Introduction to optical system design

learning resources
1. A. Rogalski, Infrared Detectors, CRC Press 2011.
2. M. Henini, M. Razeghi, Handbook of Infra-red Detection Technologies, Elsevier 2002
3. J. Piotrowski, A. Rogalski, High Operating Temperature Infrared Photodetectors, SPIE Press 2007.
4. H. Schneider, H. C. Liu, Quantum Well Infrared Photodetectors, Springer Verlag 2006.
5. H. Budzier, G. Gerlach, Thermal Infrared Sensors. Theory, Optimisation and Practice, Wiley 2011.

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 0
calculation tasks: 12
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
A. Rogalski, Infrared Detectors, CRC Press 2011.
M. Henini, M. Razeghi, Handbook of Infra-red Detection Technologies, Elsevier 2002
J. Piotrowski, A. Rogalski, High Operating Temperature Infrared Photodetectors, SPIE Press 2007.
H. Schneider, H. C. Liu, Quantum Well Infrared Photodetectors, Springer Verlag 2006.
H. Budzier, G. Gerlach, Thermal Infrared Sensors. Theory, Optimisation and Practice, Wiley 2011.

Introduction to CFD

ID: MSc-1160
responsible/holder professor: Svorcan M. Jelena
teaching professor/s: Svorcan M. Jelena
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: MFB

goals
Educate students to understand and successfully apply various procedures for efficient solution to fundamental partial differential equations derived from Navier-Stokes equations.

learning outcomes
Familiarizing the student with the computational process and available, mostly used numerical methods.

After completing the course, the student will be able to perform engineering simulations based on continuum mechanics.

Understanding of the meaning of a well posed problem and of additional conditions necessary to obtain a unique solution.

Recognition of the most influential causes of the flow behavior.

Overview of the fundamental models, boundary conditions and approximation schemes.

Implementation of personal codes and the usage of existing software to simulate simple flow problems.

theoretical teaching
Introduction to Computational Fluid Dynamics (CFD) and overview of the principal computational phases. Overview of the model partial differential equations. Analytical and numerical methods for their solution. Finite difference method. Basic approximation schemes. Solution of different types of PDE. Generation of the computational domain and an adequate grid. Boundary conditions. Stability analysis. Post-processing. Fundamentals of finite volume method.

practical teaching
Each theoretical topic is accompanied by suitable practical examples and programs that illustrate the applied numerical method and results post-processing.

prerequisite
There are no mandatory conditions/prerequisites for course attendance.

learning resources
Classroom, projector, laptop.

number of hours: 75

> **active teaching (theoretical):** 60
> lectures: 45
> elaboration and examples (revision): 15
>
> **active teaching (practical):** 10
> auditory exercises: 0
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 0
> project design: 10

consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 60
final exam: 30
requirements to take the exam (number of points): 30

references
Petrovic Z., Stupar S., "Projektovanje racunarom", Univerzitet u Beogradu, Beograd, 1992.
Anderson J.D.Jr., Computational Fluid Dynamics - The Basics with Applications, McGraw-Hill, New York, 1995.
Ferziger J.H., Perić M., Computational Methods for Fluid Dynamics, Springer-Verlag, Berlin Heidelberg, 2002.
Additional materials, lecture slides.

Introduction to Neural Networks and Fuzzy Systems

ID: MSc-1151
responsible/holder professor: Jovanović Ž. Radiša
teaching professor/s: Jovanović Ž. Radiša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The objectives of the course are:

•Introduce students to the fundamental principles of artificial neural networks and fuzzy systems.

• Introduction to the neural networks for classification, recognition and regression.

• Understanding of fuzzy approach to modeling phenomenon, process and systems and basic of fuzzy set theory and fuzzy logic.

• Mathematical modeling of artificial neural networks and fuzzy systems and its application to science and technology.

• To offer neural network and fuzzy system implementations in Matlab/Simulink software.

learning outcomes
After completing this course, students will be able to:

• Understand the concepts, and representation of most common neural network models.

• Understand the mathematical and practical concept of fuzzy sets, fuzzy logic and fuzzy system theory.

• Implement neural network models and fuzzy systems for particular applications.

theoretical teaching
Fundamentals of artificial neural networks: architecture, classification, basic properties. Neural network learning rules. Single-layer feedforward neural networks, perceptron, linear network. Multilayer feedforward networks, backpropagation learning algorithm. Radial basis function neural networks: topology, learning algorithm. Kohenen's self-organizing network: topology, learning algorithm. Recurrent neural networks: basic concepts, dynamics, architecture and training algorithms and applications. Hopfield network: topology, learning algorithm, applications. Using neural networks for classification, regression and pattern recognition.

Classical and fuzzy sets: introduction, operations and properties, membership functions. Fuzzy relations: operations and properties. Fuzzy logic: linguistic variables, fuzzy rules, approximate reasoning. Fuzzy deductions in fuzzy modeling, generalized modus ponens and modus tollens. Fuzzy systems: fuzzy rule base, fuzzy inference engine, Mamdani inference method and composition rule, fuzzification, defuzzification, mathematical representations of fuzzy systems. Mamdani and Takagi-Sugeno fuzzy systems. Fuzzy decision-making. Fuzzy integral and fuzzy measure. Fuzzy identification and estimation.

practical teaching
PA:Practical work includes computational exercises that follow the content of course.

PL:Practice and experiments: computer applications in simulation and implementation of neural networks and fuzzy systems, as well as their practical realization using Matlab and different plants within a modular educational real-time control system (inverted pendulum, ball and beam system, DC servo motor, coupled tanks experiment).

prerequisite
Defined by curriculum of the study programme.

learning resources
•Radiša Jovanović, Introduction to Neural Networks and Fuzzy Systems, Lecture notes, Faculty of Mechanical Engineering.

•Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software.

•Installation for control system testing and acquisition of electrical variables

•Intelligent Control Systems Laboratory, Control Systems Laboratory.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 10
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 50
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Radiša Jovanović, Introduction to Neural Networks and Fuzzy Systems, Lecture notes, Faculty of Mechanical Engineering
Simon Haykin, "Neural Networks and Learning Machines", Vol. 3. Upper Saddle River, NJ, USA:: Pearson, 2009.
K. M. Passino, S. Yurkovich, "Fuzzy Control", Addison-Wesley, 1998.

Introduction to optical system design

ID: MSc-1354
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal of the course Introduction to optical system design is that students learn basic facts about lens design. This means that students will learn the basic theory of geometrical optics such as the paraxial optics and the ideal optics. During course students will start to use standard program for optical design. Knowledge and skill obtained in this course will be used in following advanced courses of optical system design.

learning outcomes
At the end of the course students will have practical knowledge of the geometrical optics, optical components (lenses, mirrors, prisms) and optical materials that are necessary for studying other fields of the optical system design.

theoretical teaching
1. Conventions in optics
2. Reflection and refraction on single optical surface
3. Ideal optics
4. Basic relations between object and image
5. Paraxial optics
6. Optical invariants
7. Lenses
8. Mirrors
9. Prisms
10. Multiple component optical systems
11. Diaphragms and pupils of optical system
12. Physical characteristics of optical materials
13. Glasses
14. Special optical materials

practical teaching
1. Calculation of the raytrace in the ideal optical system
2. Calculation of the raytrace in the paraxial optical system
3. Introduction to the lens design program
4. Calculation of single lens
5. Calculation of mirrors and prisms
6. Calculation of multicomponent system

prerequisite
There is no obligatory prerequisites.

learning resources
1. Vasiljević D.: Optical instruments and optoelectronics, Faculty of Mechanical Engineering, Belgrade, 2005. (in Serbian)

2. Geary M. J.: Introduction to lens design with practical ZEMAX examples, William Bell Inc., Richmond, Virginia, USA, 2002.

3. Greivenkamp J.: Field guide to geometrical optics, SPIE Press, Bellingham, Washington USA, 2004.

4. Walker B.: Optical Engineering Fundamentals, 2nd edition, SPIE Press, Bellingham, Washington USA, 2008.

5. Standard program for lens design

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 0
calculation tasks: 12
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

M.Sc. thesis

ID: MSc-0822
responsible/holder professor: - -. -
teaching professor/s: - -. -
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 26
final exam: oral
parent department: MFB

goals
Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task within the Master thesis; understanding the principles of project and equipment design and the environment necessary for their production; designing systems, components or processes bearing in mind practical limitations, such as economic, ecological, social, ethical, health and security limitations; using computing and statistical methods, simulations and information technologies for analysis and synthesis of technological systems; implementing standard tests and measuring and providing an overview of the results. The preparation of Master thesis helps the student to acquire experience in academic paper writing and develop the ability to publicly present the results of independent work, as well as to provide answers to the questions related to the topic of the paper.

learning outcomes
Upon the successful defence of the Master thesis, engineers should be able to:

- come up with and apply the solutions based on their knowledge in sciences, engineering, technology and mathematics,
- determine, formulate, analyse and solve basic engineering problems,
- design a system, component or process, provide answers to the stated needs, plan and conduct an experiment and analyse and interpret data,
- work efficiently as individuals in a team and in a multidisciplinary environment, with the ability of lifelong learning,
- communicate efficiently with the engineering community and the society as a whole,
- apply the acquired knowledge in practice.

theoretical teaching
It is developed individually in accordance with the needs and the field encompassed by the topic of the Master thesis. Upon agreement with the mentor, the student compiles the Master thesis in written form, in keeping with the prescribed Faculty standards. The student prepares and publicly defends the written Master thesis upon agreement with the mentor. The student studies the referent literature, bachelor and master theses with similar topics and conducts analyses in order to find solutions to the specific task defined by the topic of the Master thesis.

practical teaching
Within the given topic, the student may conduct standard testing and measuring; he/she may conduct, analyse and interpret experiments and implement experimental results to process improvement. He/she may use the methods and tools for analysis, synthesis and design, such as: CAD, CAM, CAE, FEA, FMEA et al.

prerequisite
Defined by the curriculum of the study programme/module, the student must have passed the exam of the course which the Master thesis belongs to.

learning resources
Existing laboratory equipment at the Faculty, textbooks and library references.

number of hours: 330

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 285
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 270
consultations: 15
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 13
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 70

references
Current textbooks, magazines, library references in the field of the topic of the Master thesis.

Maintenance management M

ID: MSc-1233
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Perception of position and cost of maintenance within life cycle of technical systems. Acquaint ion with parameters which affect design of maintenance organization. Practical determination and analyze of technical system reliability. Acquaint ion with standard malfunctions, methods for condition monitoring as well as with equipment for condition monitoring. Overwhelm with methods for determination of replacement and reparation strategies, maintenance costs and inventory optimization. Acquaint ion with possibilities of maintenance system optimization and application of computer systems – business solutions.

learning outcomes
Curriculum overcome enables overwhelm with necessary knowledge and skills (models, optimization procedures, monitoring and measure equipment, basics of computer systems – business solutions) for implementation in maintenance organizations of complex technical systems.

theoretical teaching
Significance, organization parameters and structure of maintenance system. Reliability of technical systems – reliability of element until first failure. Empirical determination of element reliability and reliability of complex systems. Recovery process and strategies of replacements and reparations. Replacement models. Categorisation and planning of maintenance works. Standard malfunctions and methods for machine condition monitoring. Methodology for weak spots seeking. Maintenance costs. Spare parts. Inventory optimization. Inventory management – deterministic and stochastic models. Determination of indicators of maintenance system work. Queuing theory – finite source (calling population) systems. Occupational safety and health at work. Inspection and examination of work equipment. Examining the conditions of working environment. Enterprise Asset Management.

practical teaching
Audit lessons (Maintenance position in company organisation structure. Reliability of element until first failure calculation. Reliability of complex systems – examples of serial, parallel, passive parallel, partially parallel relations between elements. Strategies and models of replacements – examples with and without discount factor (rate) and with compete and partial write-off. Repair (maintenance) complexity. Weak spots. Inventory management – deterministic and stochastic models. Queuing theory – finite source (calling population) systems – models with and without help between servicing channels.). Occupational safety and health at work - practical examples.

Seminar work (Analysis of gathered data about malfunction on real system, determination of malfunction intensity, determination of probability density function of time until malfunction, using chi-square test.).

Laboratory work (Acquaint ion with standard and advanced equipment for system condition monitoring - SKF, as well as with possibilities of implementation of maintenance module in company computer systems – business solutions, using SAP EAM module).

prerequisite
There is no special conditions needed for course attending

learning resources

1. Bugaric, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011.

3. Bugaric, U.: Methodology for analysis of single position machines work, Foundation Andrejevic, Belgrade, 2003.

4. Bugaric, U., Petrovic, D.: Softvare for verification of sample belongings to theoretical distribution using chi-square test, Faculty of Mechanical engineering Belgrade, Belgrade, 1996-2010.

5. Klarin, M., Ivanovic, G., Stanojevic, P., Raicevic, P.: Principles of therotechnological actions, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.

6. Software: QtsPlus 3.0 (Queuing theory software Plus).

7. Practical instruction in industrial environment (SKF, SAP).

8. Mobile devices for measurement of temperature and vibrations.

9. Personal computers.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 10
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 3
check and assessment of seminar works: 1
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 10
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.
Stapelberg, R.F.: Handbook of Reliability, Availability, Maintainability and Safety in Engineering Design, Springer-Verlag, London, 2009.
Mobley, R.K., Higgins, L.R., Wikoff, D.J.: MAINTENANCE ENGINEERING HANDBOOK (Seventh Edition), McGraw-Hill, New York, 2008.

Manufacturing Technologies

ID: MSc-0731
responsible/holder professor: Babić R. Bojan
teaching professor/s: Babić R. Bojan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
This course is designed to provide a basic understanding of present-day manufacturing processes. The course will start by introduction to the manufacturing. Through lectures, demonstrations, and practical applications, the student will be introduced to various manufacturing processes.

Further on students will learn basic metal removal processes: turning, milling, boring and grinding. The special attention will be given to CNC machines. Material removal calculations will be introduced for each conventional process including, metal removal rate, depth of cut, cutting forces, spindle and cutting speeds. The most common non-traditional techniques will be considered in detail. Using projects and tutorials, students are motivated to develop and implement process planning skills during the course.

learning outcomes
On the completion of this module students will be able to:

1. Indicate which types of manufacturing process are suited to producing different shapes of product.

2. Indicate which processes are likely to be used for producing a particular product using a specific material or class of material.

3. Describe the advantages and disadvantages of the different classes of manufacturing processes.

4. Demonstrate good team and interpersonal skills to enhance both oral and written communication with colleagues, management and other professionals within the manufacturing industry.

theoretical teaching
Introduction - subject and importance of manufacturing technology in metalworking industry; Fundamentals of metal forming; Bulk deformation processes; Sheet metalworking; Theory of Metal Machining; Machining Operations and Machine Tools; Cutting Tool Technology; Abrasive processes; Non-traditional processes; Economic and Product Considerations in Machining.

practical teaching
Assignment: Example of metal cutting; Assignment: Example of forging; Machining systems for metal cutting (lab work); Machining systems for bulk (lab work). Designing for CNC technology .

prerequisite
Defined by curriculum of study programme/module.

learning resources
(1) B. Babic, Handouts, University of Belgrade, Faculty of Mechanical Engineering, 2011.

(2) B. Babic, Electronic classrom for distance learning (http://147.91.26.15/moodle/), University of Belgrade, Faculty of Mechanical Engineering, 2011.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 22
calculation tasks: 0
seminar works: 8
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 35
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Kalpakjian, S., Schmid R. S., Manufacturing Engineering and Technology, 6th edition, Pearson Education Inc., 2010
Groover, M. P., Fundamentals of Modern Manufacturing, 3rd edition, John Willey and Sons, 2007.

Matlab and Simulink for engineering applications

ID: MSc-1152
responsible/holder professor: Jovanović Ž. Radiša
teaching professor/s: Jovanović Ž. Radiša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
After the course the student should be familiar with how Matlab and Simulink are used in solving various engineering tasks. The student should be able to use programming packages MATLAB and Simulink in modeling, analysis, optimization and simulation of various dynamical systems (mechanical, electrical, hydraulic, thermal, and electronic).

learning outcomes
•Acquiring basic and intermediate knowledge in programming tools MATLAB and Simulink.

•Introducing and using methods for modeling, analysis and simulation of various engineering systems.

theoretical teaching
Basic Matlab: variables, vectors and matrices, operators, loops and conditional statements, functions and files. Linear and nonlinear equations. Numerical differentiation and integration. Solving differential equations. Symbolic processing. Approximation of functions and data. Creating graphics. Optimization. Statistics. Concept of dynamic systems simulation with Simulink. Combining Matlab and Simulink. Computer modeling and mathematical representation of mechanical, electrical, hydraulic, thermal, and electronic systems or combinations of these. Modeling and simulation of various dynamical systems. S-functions and simulation diagrams.

practical teaching
Practical examples that follow the content of course. Modeling, analysis and simulation of various objects on a modular educational real-time control system and acquisition of data from various peripheral devices and sensors with Matlab/Simulink.

prerequisite
Defined by curriculum of the study programme.

learning resources
•Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, 2016.

•PC computers, Computer laboratory, Faculty of Mechanical Engineering Belgrade

•Modular educational real time control system with various plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software,

•Control Systems Laboratory, Intelligent Control Systems Laboratory.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0

laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references
Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, 2016.
Amos Gilat, MATLAB - An introduction with Applications, John Wiiley & Sons, Inc., 2004.

Missile system integration (SIN)

ID: MSc-1308
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: MFB

goals
The basic goals of this course are divorced in to the informative, education and expert skill in the tactical, military, missile systems design. First is to inform applicants, and students about different number of tactical missiles systems based on their military employment. Also, these introducing students in to the interactive performances relationships which fully provides joint technology process on combat platforms integrated with missiles.

Educational, as second goal, are divorced as structural, functional and interactive expert analyses of different knowledge applied on missiles design. Students are preparing for the principals of missiles and rockets mechanics, aerodynamics, chemical propulsion (rocket and air breathing), and others science branches as bases for design missiles subsystems. Expert knowledge goals provides design of subsystems and external and internal loads which determines missiles performances, payload and ordinance, guidance, flight control and air frame. This basically are considered as function of propulsion types, orientated to the missiles mission engagements, and as, the contents of external platforms and subsystems .

Skill goals are recognized on the valid evaluation of the most important performances or parameters witch determines missile constrains and missiles systems performances both, in employment or the development phases. Students have the design tactical and technical requirements, to plain military architecture of systems and achieve skills to recommend the best employment of missiles systems in tactical applications.

learning outcomes
Students have to accept knowledge about military application of missile systems of tactical levels. Also student have to form experts knowledge about performances of each particular functional sub-assembly of missiles as linking influenced of missiles flight vehicle, and missile system combat architecture This expert knowledge understand, also, particular parameters of equipment sub-assemblies linked with missile, and their constrains influenced on merits of efficiency reliability and coast effective analyses of missile systems. Expert gets skill to design frame of tactical and technical demands for system and component integrations design.

theoretical teaching
1. Introductive considerations, military diversification of missiles and rockets, and basic elements of integration process in missiles design (tactical performances concepts dimensions, mission requirement, and basic missile-rocket concept)

2. Missile. The basics principles and theory of rocket launching and flight. Propulsion and power units types and integration performances Aerodynamics, stability and flight characteristics. Warhead Efficiency and missile payload integration. Guidance Systems, sensors and homing heads. Control Systems. Trajectory and flight performance. Mass model and the weight of tactical missiles.

3. Launcher and Fire Control Systems (FCS) (types of launcher design, initial errors of launching and influence on FCS).

4. Technology of combat architecture of missile systems employment. Organization and diversification of missile combat units. Command systems and sensors of mobile platforms. Combat effectiveness of missile complexes Influences of countermeasures. Deterministic and probabilistic mathematical methods in the efficiency estimations missile systems architecture. Price and reliability of missile complex term and cost- effectiveness.

5. The process of developing and implementing tactical missile (the requirements for performance testing missiles, airframe, flight control, guidance, launching, warheads and fuzzes and propulsion and power plants).

6. Systems and missiles Testing and Evaluation (types of tests, laboratory tests and external tests, simulation tests, combat tests of payload components, the reliability tests, electromagnetic compatibility, logistic tests and tests using the platform to a different environment, final integration and test planning and flight integration test).

practical teaching

1. Tactical and technical requirements design of missiles (warheads, payload, propulsion, homing head, guidance, control)

2. Tactical and technical requirements of launcher

3. Tactical and technical requirement of command system, targets surveillance systems links and FCS (fire control systems)

4. Tactical design of guidance and navigation control loops

prerequisite

No special requirements.

learning resources

Markovic M., Missile System Integration, University of Belgrade, Faculty of Mechanical engineering, HANDOUT.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 10
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 30
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Chin S.: Missile configuration design, The McGraw-Hill Book Company, 1961.
E. Fleeman, Missile design and system engineering. American Institute of Aeronautics and Astronautics, 2012.
Krasnov N.F. et al.: Rocket aerodynamics, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, June 1971
Архангельский И. И.: ПРОЕКТИРОВАНИЕ ЗЕНИТНЫХ УПРАВЛЯЕМЫХ РАКЕТ, МОСКВА, Издательство МАИ 2001.
Moore F.: Approximate methods for weapon aerodynamics. Progress in Astronautics and Aeronautics, 2000.

Modern Quality Approaches

ID: MSc-1306
responsible/holder professor: Veljković A. Zorica
teaching professor/s: Veljković A. Zorica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Purpose of the course is to introduce students to concepts and importance of quality in enterprises. Basic principles, methods and approaches are introduced to students.

Three main topics are Total Quality Management, ISO 9001:2015 standards and Six Sigma.

learning outcomes
After successfully completed projects and course, students should be able to use basic managerial and statistical quality methods.

Students are informed about modern and current trends in quality, methods and software for quality improvement, with a possibility of applications.

theoretical teaching
The course include following subjects: Definitions and role of quality in enterprises, from the aspects of organizations and production; Defining real needs for quality and customer view; Basic quality tools, basic management quality tools. Basic statistics tools in quality; Three major approaches TQM - Total Quality Management, Quality standards, especially SRPS ISO 9001, and System Six Sigma. TQM include Deming's approach, product characteristics, benchmarking, QFD, kayzen, 5s, etc. Quality standards are introduced to students through their structure, documentation, requests, advantages and limitations. System Six Sigma approach is represented with basic methodology DMAIC and consequent methods such as TRIZ, methods from TQM, Taguchi methods, Statistical methods etc, for every phase of DMAIC. Concept of data driven decision making is elaborated.

practical teaching
Students are introduced to software for quality methods. Main goal for students is the project based on practical examples and literature.

prerequisite
Course in statistics such as Engineering Statistics or Probability and Statistics

learning resources
All materials for successful following of the course - handouts, books and other materials are distributed to students before lectures in electronic form. Part of the literature for projects.

number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 40
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30

consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 9
colloquium, with assessment: 0
test, with assessment: 0
final exam: 1

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 60
final exam: 30
requirements to take the exam (number of points): 31

references

Stapenhurst T(2005) Mastering Statistical Process Control A Handbook for Performance Improvement Using Cases,Elsviere

Pyzdek, T (2003) The Six Sigma Handbook: The Complete Guide for Greenbelts, Blackbelts, and Managers at All Levels, McGraw Hill

Additional literature connected with project, individualy designed for project

Multidisciplinary Optimization in Aerospace Engineering

ID: MSc-1352
responsible/holder professor: Svorcan M. Jelena
teaching professor/s: Svorcan M. Jelena
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: MFB

goals
Familiarize students with multidisciplinary design methodology of aeronautical (aerospace) parts and assemblies that serves to produce, through multi-criteria optimization, advanced and contemporary engineering systems customized to various real operating conditions.

learning outcomes
Understanding the complex and multi-phase design process of aerospace structures. Comprehending the most influential factors and initial requirements that dictate the efficiency of the designed part.

Appropriate definition of input and output parameters (geometric, aerodynamic, structural, etc) and constraints. Understanding and singly realizing different optimization techniques (including multi-criteria and multidisciplinary). Achieving increased flexibility in the design of aeronautical parts.

theoretical teaching
The importance of multidisciplinary approach when designing aerospace structures. Definition of the optimization problem (linear and non-linear). Overview of mostly employed input and output parameters (goal functions) and constraints. Theoretical basics and implementation of different optimization methods (direct and heuristic). Use of various optimization tools. Combining the optimization and predictive tools. Multi-criteria optimization and computation of Pareto front.

practical teaching
Each theoretical topic is accompanied by suitable practical examples, exercises and programs/codes from the area of aerospace engineering.

prerequisite
There are no mandatory conditions/prerequisites for course attendance.

learning resources
Classroom, projector, computer/laptop.

number of hours: 75

active teaching (theoretical): 28
lectures: 20
elaboration and examples (revision): 8

active teaching (practical): 42
auditory exercises: 7
laboratory exercises: 7
calculation tasks: 14
seminar works: 0
project design: 14
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 20

references
Rao S: Engineering optimization: theory and practice. John Wiley & Sons, Inc., 2009.
Papalambros P, Wilde D: Principles of optimal design: modeling and computation. Cambridge University Press, 2000.
Weise T: Global Optimization Algorithms – Theory and Application. E-book, 2009.
Haupt R, Haupt SE: Practical genetic algorithms. John Wiley & Sons, Inc., 2004.
Additional materials, lecture slides.

Nozzle Flow Analysis and Thrust Vector Control Systems

ID: MSc-0777
responsible/holder professor: Miloš V. Marko
teaching professor/s: Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: MFB

goals
Objective of the Course is providing insight in the fundamentals and physics of the nozzle flow as well as insight in mathematical modeling of this phenomena. The Course is set up to deliver engineering tools for advanced propulsion problems and fundamentals of thrust vector systems.

learning outcomes
Upon completion and passing the course the student is expected to understand the basic concepts and problems addressed in the field of nozzle flows and Thrust Vector Control Systems. It is expected that the student knows how to apply the acquired knowledge in this field to solve practical engineering problems in the area of propulsion.

theoretical teaching
Review of fundamental concepts of gas dynamics. Basic nozzle types and their applications. Most important nozzle geometrical and gas parameters. Ideal nozzle concept (characteristics flow zones & methods of analyses). Basic nozzle design: convergent and convergent-divergent nozzles. Advanced nozzle design problems. Conical, bell, double bell, annular, spike and expansion-deflection nozzles. Nozzle flow field characteristics and performances. Real nozzles characteristics (losses types and overall efficiency analysis). Flow separation in the nozzles. Experimental testing and measurements. Application of CFD in nozzle flow analysis. Software application examples (1D, 2D and 3D software). Nozzle design examples. Principle of work & overview of TVC systems. System design. Component design (movable nozzle vs fixed nozzle). SRM TVC System and LRE System (laboratory demonstration and practice).

practical teaching
Practical part of Course demonstrate the numerical examples in all areas of nozzle applications. Practical work of students is realized through a virtual classroom available 24 hours (program MOODLE). In the workshop students have approach to the professor's written notes, lectures, tests for practice and quizzes (each student works individually).

prerequisite
None

learning resources
This Course has a virtual classroom on the Internet. At the first lecture students are enrolled and trained for work (Moodle software). In the workshop approach is performed with the lectures and exercises, guidelines for project design, internet resources, etc.

number of hours: 75

> **active teaching (theoretical):** 45
> lectures: 35
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 15
> laboratory exercises: 0

calculation tasks: 0
seminar works: 10
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 0
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)

feedback during course study: 15
test/colloquium: 25
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references

Zoran Stefanović, Marko Miloš: Handouts for Nozzle flow Analysis and TVC Systems, Faculty of Mechanical Engineering, 2012.
E.Greitzer, C.Tan, M. Graf: Internal Flow, Cambridge University Press, 2004
Zucrow & Hoffman: Gas Dynamics, Vol 1 , Vol 2, John Wiley & Sons, 2005
J. Anderson: Modern Compressible Flow, McGraw Hill, 2002
J.John, T.Keit: Gas Dynamics, Pearson Hall, 2006

Nuclear Power Plants Safety

ID: MSc-1408
responsible/holder professor: Stevanović D. Vladimir
teaching professor/s: Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: MFB

goals
Study of influences of nuclear power plants (NPPs) on the environment:

(a) under normal operation,

(b) during and after the hypothetical accidents with the violation of the barriers to the release of the radioactive material to the environment. Analyses of hypothetical transient and accident conditions of the NPPs that endanger NPP's safety and threatens to the security of operating staff, environment and people include: small and large loss of coolant accidents, loss of feedwater accidents, nuclear reactor power excursions, NPP blackouts, etc. Study of active and passive safety systems at the NPP. Study of advanced reactor systems: generation III+, generation IV and small modular reactors.

learning outcomes
Development and application of thermal-hydraulic models for computer simulations and analyses of nuclear power plant transients and accident conditions. Analyzing efficiency of safety systems in mitigating consequences of plant abnormal conditions on environment.

theoretical teaching
Nuclear reactor steady state and transient operation. Coupling of thermal-hydraulic and neutron kinetics. Thermal feedback mechanisms. Sources and intensity of disturbances. Active and passive safety systems. Thermal-hydraulic models and computer codes. Safety analyses and risk studies.

practical teaching
Development of a thermalhydraulic model and a computer code for the simulation of behaviour of a chosen nuclear power plant component or system. Application of the developed model and code to the safety analyses.

prerequisite
Passed exams in Thermodynamics, Fluid Mechanics and Higher Mathematics at Bachelor or Master university studies.

learning resources
Lecture notes, computer equipment, in-house and commercial computer codes for two-phase flow simulations.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 15
> laboratory exercises: 15
> calculation tasks: 0
> seminar works: 0
> project design: 0

consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 35
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Klimov, A., Nuclear Physics and Nuclear Reactors, Mir Publishers, Moscow, 1981.
Tong, L.S., Design Improvement for Light Water Reactors, Hemisphere, New York, 1988.
Knief, R.A., Nuclear Energy Technology, Hemisphere, 1981.
Foster, A., Wright, R.L., Basic Nuclear Engineering, Allyn and Bacon, Inc., Boston, 1977.

Numerical analysis in warhead design

ID: MSc-1313
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal of the course is to introduce student in the specific field of numerical simulations applied for the warhead design. Experimental/empirical investigations in this domain are very expensive in terms of the equipment, setup, needed time and costs. Therefore, the use of numerical simulations for the key processes of interest, e.g. impacts, penetration/perforation, explosions, explosive propulsion, fragmentation, can be of great importance in design/redesign of warheads.

learning outcomes
After successfully completed course, a student should be able to:

- understand all relevant concepts of numerical approach to the warhead and terminal ballistic mechanisms,

- apply the finite element method (FEM) to the problems relevant for warhead design,

- efficiently use a program for numerical simulations of transient phenomena relevant for terminal ballistics and warhead mechanisms,

- perform simulations and analyze obtained results.

theoretical teaching
1. Modeling in warhead design and terminal ballistics

2. Numerical vs. analytical and empirical approach

3. Dynamic behavior of materials. Metals. Explosives

4. Experimental methods for material behavior at high strain rates

5. Conservation equations. Constitutive models

6. Lagrangian and Eulerian framework. Coupled Eulerian-Lagrangian (CEL) approach

7. Hydrocodes – fundamentals of working principles

8. Impact, penetration, wave propagation. Shock waves in solids

9. Explosive propulsion treatment in numerical simulations

10. Modules of a program for numerical simulation (hydrocode)

11. Preprocessing, processing and postprocessing stages in numerical simulation

practical teaching
1. Dynamic behavior of materials. Examples: Johnson-Cook (JC) model, Jones-Wilkins-Lee (JWL) model

2. Experimental methods for material behavior at high strain rates. Examples: Taylor test, Hopkinson bar

3. Impact, penetration, wave propagation. Application of 1D shock wave theory

4. Modules of a hydrocode - examples

5. Preprocessing, processing and postprocessing stages in numerical simulation - examples in penetration and explosive propulsion

6. Various examples (HE warheads with premade fragments, ballistic perforation, shaped charge formation, perforation of shaped charge jet, blast action on a structure)

prerequisite
No.

learning resources
1. Zukas, J.A.: Introduction to Hydrocodes, Studies in Applied Mechanics, Elsevier, 2004.

2. Meyers, M.A.: Dynamic behavior of materials, John Wiley and Sons, 1994.

3. Zukas, J.A., Walters, W.P.: Explosive effects and applications, Springer, 1997.

number of hours: 75

active teaching (theoretical): 30
lectures: 15
elaboration and examples (revision): 15

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Numerical Methods

ID: MSc-1161
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Purpose of the subject is to introduce basic numerical methods useful in everyday engineering calculations. Applications are illustrated by short MatLab programs. Students are enabled to modify these programs according to their needs.

learning outcomes
After passing this exam students will be capable to understand application of numerical methods applied to solution of engineering problems. Students will be also capable to recognise when certain numerical methods should be applied in engineering applications. Ability to numerically interpolate, integrate, differentiate, solve system of equations, solve ordinary differential equations, apply FFT analysis. Apply Matlab to implement numerical methods.

theoretical teaching
The following topics are contained in this course: Introduction to simulation, Matlab in short, Approximate calculations, Interpolation, Solution of systems of linear algebraic equations, Solution of nonlinear equations, Numerical differentiation, Numerical Integration, Ordinary differential equations, Determination of eigenvalues, Partial differential equations, Finite difference method, Finite volume method.

practical teaching
For each topic are presented one or more MatLab examples (dependent on topic). This examples are used to illustrate solution procedure tied to the topic. Each student get unique combination of problems for each topic which is left as homework. Quality of student response to the problems contribute to final grade of this subject.

prerequisite
None.

learning resources
Computer lab, beam projector, laptop

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 30
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 36
> auditory exercises: 10
> laboratory exercises: 5
> calculation tasks: 10
> seminar works: 0
> project design: 10
> consultations: 1
> discussion and workshop: 0
> research: 0

knowledge checks: 9
check and assessment of calculation tasks: 2
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 30

references
John H. Mathews, Kurtis D. Frank, "Numerical Methods Using MATLAB", Prentice-Hall, 1999, New Jersey
Joe D. Hoffman, "Numerical Methods for Engineers and Scientists", McGraw-Hill, Inc. New York, 1992
Lecture notes and lecture slides

Numerical Methods in Heat and Mass Transfer

ID: MSc-1236
responsible/holder professor: Milivojević M. Aleksandar
teaching professor/s: Milivojević M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The objectives of the subject are to introduce the students with numerical methods in general and with heat and mass transfer problems, in particular and to familiarize students with the CFD elements.

learning outcomes
To encourage and enable students to use numerical methods in practice.

theoretical teaching
Topics

1. Introduction to numerical methods.
2. Conservation equations.
3. Heat and mass transfer.
4. Mechanisms of heat and mass transfer.
5. Turbulence; Two phase flows.
6. Boundary conditions; Meshing;
7. Solution methods.

practical teaching
Practical tuition includes analysis and examples of conservation of mass and energy laws, introduction to the CFD, and use of CFD to solve a problem in practical heat/mass transfer situation.

prerequisite
Thermodynamics B exam passed

learning resources
The subject Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 10
calculation tasks: 5
seminar works: 5
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 5
calculation tasks: 5
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
The Handouts
S. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw Hill, New York, 1980.
Anon. ANSYS FLUENT CFD Code Manual, 2010.
R. Bird, W. Stewart, E. Lightfoot, Transport Phenomena, Willey International, 1960.

Principles of warhead mechanisms

ID: MSc-1353
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The main objective of the course is that students get basic knowledge of principles of mechanisms for fragmentation, blast, shaped charge, EFP, KE-rod and special warheads. These fundamentals are important for understanding of projectile design and terminal ballistics.

learning outcomes
Student gets contemporary knowledge about main principles of modern warhead mechanisms. Student understand the physics of fragmentation, blast, shaped charge, KE-rod and special warhead mechanisms and performs fundamental calculations of relevant warhead parameters.

theoretical teaching
Introduction to warheads. Classification of warhead types. Mechanics of high-explosive warheads. Warhead disposition. Warhead action on target. Target characteristics. Kill probability of target.

Fragmentation warhead principles. Controlled warhead fragmentation. Premade fragments warheads.

Blast warheads.

Influence factors on shaped charge effect. Jet formation theory.

Explosively formed projectiles.

Kinetic energy (KE) rod warheads.

Special warheads.

practical teaching
Fragmentation warhead principles. Safety during the flight. Simulation of warhead action.

Blast warheads. Blast crater characteristics.

Influence factors on shaped charge effect. Simulation of jet formation and penetration.

Explosively formed projectiles. Calculation of velocity of EFP.

Kinetic energy (KE) rod warheads. Selected problems.

prerequisite
No.

learning resources
1. Jaramaz, S.: Warheads Design and Terminal Ballistics, Faculty of Mechanical Engineering, Belgrade, 2000.

2. Carleone, J.: Tactical Missile Warheads, AIAA, 1993.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 10
seminar works: 5
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Lloyd, R.M.: Conventional Warhead Systems Physics and Engineering Design, Progress in Astronautics and Aeronautics, Volume 79, AIAA, 1998.

Production and operations management 1 - M

ID: MSc-1238
responsible/holder professor: Spasojević-Brkić K. Vesna
teaching professor/s: Spasojević-Brkić K. Vesna
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals

The aim of this course is to acquire knowledge and practical skills in the field of theory and practice of the production and operations management. Mechanical engineers after taking this course are trained to perform diagnostics and to apply methods for raising the level of enterprise organisation and rationalisation of operations and production. Methods and techniques for production and operations management are useful in everyday tasks of mechanical engineers irrespective of the job specialisation.

learning outcomes

Upon successful completion of this course, student acquires the following competencies: 1. Diagnosing the state of the organisation of the company, 2. Organisational structure design , 3. Tools for rationalisation of production and operations processes application in the company 4. Analysis of the success rate of an enterprise and accordingly are able to diagnose the level of organisation and 5. Explain the connection between the above mentioned competencies to make decisions, and, accordingly upon the course completion is able to design organisational structure and make rationalisation of production processes according to calculated success rates. After completion of the course students also demonstrate an awareness and an appreciation of the importance of the operations and production management to the sustainability of an enterprise and are trained to solve real problems using scientific methods and techniques of production and operations management.

theoretical teaching

Basic concepts of production and operations management. Modern tendencies in the production and operations management. Principles of structuring of the production system. Types of organizational structures. Production scheduling charts. Techniques of network planning - CPM/PERT.Material Requirements Planning. Inventory management. The function of planning and analysis. Production cycle time. The calculation of production capacity. Production planning and capacities analysis. Linear programming. Types of production. Technical and technological documentation. Time structure of the production cycle. Inventory control. Maintenance management. Quality management in manufacturing companies. Indicators of financial performance. Designing organisational structure according to specific context.

practical teaching

Design of Macro-organisational structure of manufacturing enterprises with particular emphasis on the organisational structure of the production function micro level. Solution of practical problems in the areas of linear programming, CPM/PERT, inventory management and capacities calculations and production cycle time and capacities measurement. The corporate performance measures calculation.

prerequisite

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learning resources

1.Tersine J.R., Production/Operations Management: Concepts, Structure and Analysis, Appleton & Lange, New York, 2005.

2. Stevenson, W. J. (2005). Operations management. Mc Graw-Hill.

3. Chan, L. M., Shen, Z. M., Simchi-Levi, D., & Swann, J. L. (2004). Coordination of pricing and inventory decisions: A survey and classification. In Handbook of quantitative supply chain analysis (pp. 335-392). Springer, Boston, MA.

4. Chase, R. B., Aquilano, N. J., & Jacobs, F. R. (2001). Operations management for competitive advantage (Vol. 9). Boston, MA: McGraw-Hill Irwin.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 1
laboratory exercises: 0
calculation tasks: 14
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 2
test, with assessment: 1
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 30

references
Tersine J.R., Production/Operations Management: Concepts, Structure and Analysis, Appleton & Lange, New York, 2005.
Stevenson, W. J. (2005). Operations management. Mc Graw-Hill.
Chan, L. M., Shen, Z. M., Simchi-Levi, D., & Swann, J. L. (2004). Coordination of pricing and inventory decisions: A survey and classification. Springer,.
Chase, R. B., Aquilano, N. J., & Jacobs, F. R. (2001). Operations management for competitive advantage (Vol. 9). Boston, MA: McGraw-Hill Irwin.

Production Planning and Control

ID: MSc-1099
responsible/holder professor: Babić R. Bojan
teaching professor/s: Babić R. Bojan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The purpose of this course is to develop knowledge and skills in the function, terminology and organisational relationship of production planning and control within a manufacturing environment.

learning outcomes
After successful completion of the course student will able to:

1.Demonstrate and explain the use of Manufacturing Requirements Planning (MRP2), Just - In - Time (JIT) techniques in terms of operation and their importance in Lean World Class Manufacturing.

2.Prepare a work estimate of a specified manufacturing product and explain the importance of value analysis/ value management for both product and process design.

3.Explain various production control methods which can be applied to specific situations and state their relationship to the product/process involved.

4.Outline the process and procedures from sales to the shop floor required to obtain an authority to commence production.

5.Apply scheduling and material control techniques to various specified situations. Include an explanation of the need for inventory minimisation procedures and how these might conflict with delivery response objectives.

theoretical teaching
Introduction

Production planning and control: role and impact

Production systems

Classification of production systems

Plant location and layout

Factors influencing plant/facility location

Plant layout

Classification of layouts

Design of product layout

Design of process layout

Material handling

Objectives of material handling

Principles of material handling

Selection of material handling equipment

Principles of Production Planning and Control

Project planning techniques

Operations planning and scheduling systems

Materials requirements planning (MRP)

Enterprise requirements planning (ERP)

Introduction to planning and scheduling

Planning and Scheduling: Role and Impact

Planning and Scheduling Functions in Manufacturing

Manufacturing Models

Jobs, Machines, and Facilities

Processing Characteristics and Constraints

Performance Measures and Objectives

Planning and Scheduling in Manufacturing

Project Planning and Scheduling

Machine Scheduling and Job Shop Scheduling

Scheduling of Flexible Assembly Systems

Economic Lot Scheduling

Planning and Scheduling in Supply Chains

practical teaching
Laboratory work includes computer-aided applications and programming of automated production equipment.

prerequisite
Defined by curriculum of study programme/module.

learning resources
(1) B. Babic, Handouts, University of Belgrade, Faculty of Mechanical Engineering, 2016.

(2) AnyLogic simulation software

(3) B. Babic, Software packages for process planning

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 8
calculation tasks: 3
seminar works: 0
project design: 15
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 2
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 35
final exam: 30
requirements to take the exam (number of points): 30

references
Groover, M. P., Automation, Production Systems, and Computer-Integrated Manufacturing, 3rd Ed. Pearson Education, 2008

Project Management

ID: MSc-0749
responsible/holder professor: Babić R. Bojan
teaching professor/s: Babić R. Bojan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: MFB

goals
The management of projects is a key element for successful scientific investigation of activities related to academic research, company research and development or consultancy. Through this course learners will develop an understanding of what constitutes a project and the role of a project manager. They will examine the criteria for the success or failure of a project, evaluate project management systems and review the elements involved in project termination and appraisal.

Learners will also understand the need for structured organisation within the project team, effective control and coordination and good leadership qualities in the project manager. They will be able to analyse and plan the activities needed to carry out the project, including how to set up a project, how to control and execute a project, and how to carry out project reviews using a specialist software package for project management. They will also appreciate how the project fits into the strategy or business plan of an organisation.

learning outcomes
On completion of this unit a learner should:

1 Understand the principles of project management

2 Be able to plan a project in terms of organisation and people

3 Be able to manage project processes and procedures.

theoretical teaching
Project management: project management and the role of the project manager eg

management of change, understanding of project management system elements and their

integration, management of multiple projects, project environment and the impact of external influences on projects; identification of the major project phases and why they are required; an understanding of the work in each phase; the nature of work in the lifecycles of projects in various industries

Success/failure criteria: the need to meet operational, time and cost criteria; define and measure success, work breakdown structure (WBS), project execution strategy and the role of the project team; consideration of investment appraisal eg use of discount cash flow (DCF) and net present value (NPV); benefit analysis and viability of projects; determine success/failure criteria; preparation of project definition report;

Project management systems: procedures and processes; knowledge of project information support (IS) systems; how to integrate human and material resources to achieve successful projects

Organisational structure: functional, project and matrix organisational structures eg consideration of cultural and environmental influences, organisational evolution during the project lifecycle; job descriptions and key roles eg the project sponsor, champion, manager, integrators; other participants eg the project owner, user, supporters, stakeholders

Roles and responsibilities: the need for monitoring and control eg preparation of project plans, planning, scheduling and resourcing techniques,

Control and co-ordination: use of work breakdown structures to develop monitoring and control systems, monitoring performance and progress measurement against established targets and plans; project reporting; change control procedures;

Human resources and requirements: calculation; specification; optimisation of human

resource requirements; job descriptions

practical teaching
Demonstration of project control and reporting techniques by using appropriate project management software. The following phases should be covered: Project initiation phase – Creation of initiation report, Making of conception report, Feasibility report forming.

prerequisite
Defined by curriculum of study programme/module.

learning resources
Appropriate software packages will be needed to demonstrate project control and reporting techniques. Packages might include time and cost scheduling packages, documentation and procurement control packages, spreadsheet packages, graphic presentation packages.

B. Babic, Electronic classrom for distance learning (http://147.91.26.15/moodle/), University of Belgrade, Faculty of Mechanical Engineering, 2011,

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 22
calculation tasks: 0
seminar works: 8
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 35

project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Harvey Maylor, Project Management, Financial Times Press, 2010
Carl Chatfield and Timothy Johnson, Microsoft Office Project 2003 Step by Step, Microsoft Press, 2004

Propulsion Systems

ID: MSc-0980
responsible/holder professor: Miloš V. Marko
teaching professor/s: Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: MFB

goals
Course objective is to introduce students to the types and principles of functioning of propulsion systems, as well as their domains of use.

Furthermore, the relation between the type of the flying object and propulsion system is pointed out, so that each mission can be realized in an optimal way according to the desired goals and constraints.

learning outcomes
By mastering this course, a student acquires abilities to perform analysis and synthesis of the whole system that consists of the flying object and its power elements. A student gains knowledge on structures of the various types of propulsion systems and components they are made of. Based on the acquired knowledge on the propulsion systems performances, a student is able to form an opinion on the quality of usually used engines and will acquire knowledge necessary for further self-improvement.

theoretical teaching
Types of the propulsion systems.
Aircraft propulsion systems.
Missile propulsion systems.
Domains of use of certain engine types.
Current problems, trend and perspectives of propulsion.

practical teaching
Practical work consists of presentation of examples and their analysis and discussion of the previously presented theory.

Visiting to propulsion laboratory.

prerequisite
none

learning resources
Moodle (Modular Object-Oriented Dynamic Learning Environment , a free, open-source PHP web application for producing modular internet-based courses that support a modern social constructionist pedagogy).

Lectures, power point presentations, room equipped with computers & software for design and simulations, handouts.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 30
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 35
> auditory exercises: 25
> laboratory exercises: 0

calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 40
project design: 0
final exam: 60
requirements to take the exam (number of points): 40

references
M.Milos, professor's handouts

Pyrotechnic security

ID: MSc-1406
responsible/holder professor: Jevtić T. Dejan
teaching professor/s: Jevtić T. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The main objective of the course is that students get basic knowledge of damages caused by explosive materials and protection by limitation of these damages, of causes of accidental explosions of explosive materials and protection against these causes. This knowledge is applied in the methods of analysis of the security of systems (Preliminary risk analysis - PRA, Failure mode and effects analysis - FMEA, Fault tree analysis - FTA).

learning outcomes
Student gets contemporary knowledge about main principles of modern methods of analysis of security of systems. Student understand and is capable to apply the principle methods of analysis of security of systems (Preliminary risk analysis-PRA, Failure mode and effects analysis-FMEA and Fault tree analysis-FTA).

theoretical teaching
Damage caused by explosive materials. Principal harmful effects of explosions of explosive materials (Local fire effect, Local destruction effect, Blowing effect, Excitation by influence effect, Fragments effect). Danger zones (areas) for equipment damage and human body injuries. Protection by limitation of damage caused by explosive materials. Means of overall (in bulk) limitation and separate limitations of harmful effects. Security distances regularization. Reduction of security distances by screens and embankments. Notion of the security margin. Causes of accidental explosions of explosive materials. Sensitivity of explosive materials on thermal and mechanical stresses and on detonation. Susceptibility of explosive materials vis-a-vis diverse chemical affinities. Critical conditions for detonation of propellants Protection against causes of accidental explosions of explosive materials. Pyrotechnic mixtures. Light producing compositions. Heat producing compositions. Smoke generating mixtures. Pyrotechnic delays. Safety of pyrotechnic compositions. Security of systems. Evaluation of risks. Probability of occurrence of an event. Amount of consecutive losses. Methods of analysis of the security of systems.

Preliminary risk analysis (PRA).

Failure mode and effects analysis (FMEA).

Fault tree analysis (FTA).

practical teaching
Overall limitation of harmful effects: Classification of dangerous materials recommended by United Nations (danger classes). Storage compatibility groups for explosives and explosive-containing devices. Classification of pyrotechnics. Preliminary risk analysis (PRA). Selected examples. Example of application of Failure mode and effects analysis (FMEA) - Workshop for nitration of hexamine. Example of application of Fault Tree Analysis (FTA) - Pyrotechnic system GSS 60

prerequisite
No.

learning resources

1. Quinchon J., Amiable R., Chereau, P., Security and labor hygiene in the industry of explosive substances, handbook, ENSTA, Paris, France (in french).

2. DOE Explosives Safety Manual, DOE M 440.1-1, Lawrence Livermore National Laboratory WSS version, CA, USA, 2001.

3. J. H. McLain, Pyrotechnics from the Viewpoint of Solid State Chemistry, The Franklin Institute Press, Philadelphia, PA, USA, 1980.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references

Quality Assurance and Tests

ID: MSc-1162
responsible/holder professor: Peković M. Ognjen
teaching professor/s: Peković M. Ognjen
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
To educate students to design, survey and study quality systems of products and services.

To educate students to design measuring testing procedure to estimate quality of manufactured product.

learning outcomes
Ability to design and lead quality system of products and services.

Able to distinguish between quality control and quality assurance.

Able to apply quality system standard.

Ability to project quality planning, quality plan, inspection and test plan.

Able to develop and prepare quality system documents.

Understand and apply certification process.

theoretical teaching
Introduction to quality assurance and quality control.

Methods and means of Quality control.

Quality and value, different views of quality.

Probability and statistics.

Estimation of statistic parameters.

Sampling Theory, Confidence intervals, Hypothesis tests.

Measurements, tolerances and quality.

Statistical quality control.

Quality management.

practical teaching
Each topic is illustrated by practical examples.

After each topic students prepare answer to homework requirements.

Final exam is presentation of seminar work done during semester.

prerequisite
No prerequisites.

learning resources
Laptop, Beam projector

number of hours: 75

active teaching (theoretical): 50
lectures: 40
elaboration and examples (revision): 10

active teaching (practical): 20
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 50
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
Lecture Notes and Lecture Slides

Seekers

ID: MSc-1156
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Acquiring knowledge in the field of missile seekers with the possibility of applications in the fields of research and development, designing, manufacturing, marketing, operational use and analysis of modern missile seekers.

learning outcomes
The student acquires general knowledge in the areas of analysis and design of missile seekers that enables participation and communication in work teams involved in the development of guided missiles. It has acquires knowledge in the areas of testing of missile guidance system, specially seekers and integration with missile guidance system.

theoretical teaching
Missile seeker systems, definition and basic concept. Passive, active and semi-active seekers.Atmospheric transmission. Radar seekers, angle and range measurement. The radar equation. Radar bands. Passive missile seekers, seeker resolution. Radar vs IR seeker detectors. Focal plane arrays. Gyros stabilized platforms. TV camera , IR camera seekers. Laser seekers.

practical teaching
Basic principle of seeker calibration. Hardware in the loop test with different types of seekers.

prerequisite
none

learning resources
Handouts,

P. Zarchan, Tactical Missile Guidance. New York: John Wiley and Sons,Inc, 1990.

Principles of Infrared Technology: A Practical Guide to the State of the Art

By John Lester Miller,Boston, MA : Springer US, 1994.

number of hours: 75

> **active teaching (theoretical):** 25
> lectures: 20
> elaboration and examples (revision): 5
>
> **active teaching (practical):** 35
> auditory exercises: 5
> laboratory exercises: 10
> calculation tasks: 5
> seminar works: 15
> project design: 0
> consultations: 0
> discussion and workshop: 0
> research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 25
project design: 0
final exam: 45
requirements to take the exam (number of points): 0

references
A. Rogalski, Infrared Detectors, CRC Press 2011.
M. Henini, M. Razeghi, Handbook of Infra-red Detection Technologies, Elsevier 2002
H. Budzier, G. Gerlach, Thermal Infrared Sensors. Theory, Optimisation and Practice, Wiley 2011.

Skill Praxis M

ID: MSc-1235
responsible/holder professor: Miloš V. Marko
teaching professor/s: Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: MFB

goals
Practical experience in ambient similar to the ambient where the graduated student - mechanical engineer will realize his own professional carrier.

Preferable almost obligatory: practical work needs to be close connected with subject of MSc thesis.

learning outcomes
Students acquire necessary experience and/or data to successfully finish MSc thesis.

Student may be introduced in business communication, design processes, development processes and manufacturing.

Students can reach practical experiences about the organization and functioning the business systems that deal in mechanical engineering.

theoretical teaching
-

practical teaching
The skill praxis is organized in a way which is the most appropriate for the student.

Practical work must be realized in the company where the mechanical engineering is the primary occupation. What the student will work, see or follow must be defined in coordination with the professor.

Generally, student can realize practical work in: manufacturing companies design companies, companies which work maintenance in mechanics or in laboratories that belong to the Mechanical faculty.

After finishing the practical work, the student must prepare the Report and this Report needs to be defended in front of professor.

prerequisite
-

learning resources
Initial resources are laboratories that belong to the Mechanical faculty.

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 90
> auditory exercises: 0
> laboratory exercises: 45
> calculation tasks: 0
> seminar works: 0

project design: 0
consultations: 0
discussion and workshop: 0
research: 45

knowledge checks: 0
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 70
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references

Solid - state lasers

ID: MSc-1356
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The goal is to introduce students to basic principles of Solid state laser design. After short introduction to light emission, absorption and amplification, students will learn the physics of solid state active materials, laser resonators, laser pumping, amplification and heat removal, as well as physics of short and ultra short pulse generation. During the course a series of demonstration experiments will be presented.

learning outcomes
At the end of the course students will have theoretical and practical knowledge of the solidstate laser design. They will be able to understand the principles of modern laser design and to actively do the research of their own.

theoretical teaching
1. Absorption, spontaneous and stimulated emission of radiation
2. Basic principles of light amplification (3 and 4 level systems)
3. Active materials for solid-state lasers
4. Laser resonator analysis and design (longitudinal and transverse modes)
5. Pumping of solid-state laser (using lamps or laser-diodes)
6. Heat removal and thermal effects
7. Q-switching and short pulse generation
8. Mode-locking and ultra-short laser pulses generation
9. Laser-induced damage
10. Key applications of solid state lasers (material processing, rang-finding, medical…)

practical teaching
1. Diode pumped Nd-YAG laser alignment and output parameter measurement

2. Second harmonic generation in a Nd-YAG laser

3. Measurement of Erbium-glass laser parameters

4. Experimental analysis of a laser resonator, longitudinal and transverse modes

5. Q-switching in a pulsed Nd-YAG laser; pulse parameter measurement.

prerequisite
There is no obligatory prerequisites.

learning resources
1. W. Koechner, Solid state laser engineering, Springer; 6th, rev. and updated ed. edition edition (2006)

2. O. Svelto, Principles of lasers, Springer; 5th ed. 2010 edition (December 28, 2009)

All practical teaching will be given in the Laboratory for holography, optical materials and photonic cristals, Photonics Center, Institute of Physics, University of Belgrade.

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 25
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Solid propellant motor design

ID: MSc-1105
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The course is designed for students who wish to acquire an understanding of the fundamental concepts and basic analyses of solid propellant motor performances. It will provide an introduction to the design of this type of rocket propulsion units.

learning outcomes
After successful completion of the course, students should be able to:

- fully understand operational principle and the role of all subsystems of a solid propellant rocket motor,
- understand main properties of different types of solid propellants,
- define and analyze the burning rate of solid propellants,
- independently calculate the "interior ballistics" of a solid propellants rocket motor,
- analyze different propellant grain configurations,
- perform initial design of solid propellant rocket motor.

theoretical teaching
1. Fundamental concepts and main parts of solid propellant rocket motors
2. Nozzle gas flow
3. Thrust of a rocket motor
4. Solid propellant burning rate
5. Pressure in the motor chamber
6. Influence of the initial temperature
7. Nozzle design
8. Propellant grain configurations
9. Motor design practices
10. Testing and verification

practical teaching
Practical work consists of presentation of examples, their analysis and discussion of the previously presented theory.

1. Nozzle gas flow, examples of calculations of an ideal rocket motor
2. Thrust of a rocket motor, examples (influencing parameters)
3. Determination of the main performance parameters from experimental data
4. Solid propellant burning rate (influences of initial tempearture, erosive burning)
5. Applications of the equilibrium pressure equation

6. Propellant grain configurations (calculation of cylindrical grain, star, etc.)

7. Testing techniques

prerequisite
Passed exams (preferred): Fundamentals of projectile propulsion, Thermodynamics B

learning resources
1. Sutton, G.P., Biblarz, O.: Rocket propulsion elements, 7 ed, John Wiley and Sons, 2001.

2. Hill, P., Peterson, C.: Mechanics and Thermodynamics of Propulsion, Pearson, 2010.

3. Elek, P.: Solid propellant rocket motor - lectures, Faculty of Mechanical Engineering, Belgrade, 2016.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 10
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Structure Analysis

ID: MSc-0735
responsible/holder professor: Grbović M. Aleksandar
teaching professor/s: Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Primary objectives of the course are as follows:

1. To understand the role of analysis in the structural design process

2. To understand the theory that underlies the classical methods of analysis

3. To become proficient in applying the classical methods of analysis

4. To learn a general framework for structural analysis (which includes modeling, selection of method, application of method and checking of results).

5. To understand the role of FEM in the structural analysis problems

6. To learn how to use ANSYS in solving simple 2D and 3D structural problems

learning outcomes
This course will give students a sense of how the methods of structural analysis can be used, not only to calculate the response of structures that have already been defined, but also to develop a more fundamental understanding of structural behaviour that can be used in design.

By completing the course, students will acquire a foundation of knowledge of completed works of structural engineering and will be able to solve fundamental structural problem using software for finite element analysis (ANSYS).

theoretical teaching
1. Introduction

- Review of basic concepts

- Equilibrium Equations

- Constitutive Relations/Force-displacement Relations

- Compatibility Conditions

2. Analysis of Statically Determinate Structures

- SF,BM diagrams

- Determination of forces in trusses, frames and cables

3. Principle of virtual work

4. Energy Principle

5. Maxwell's and Betti's laws

6. Computation of Displacements

- Moment area method

- Virtual work methods

7. Introduction to statically Indeterminate Structures

- Concept of static and kinematic indeterminacy

- Determination of static and kinematic redundancy

8. Force Method - Introduction and Applications

- Axially loaded members

- Plane truss

- Beams

- Frames

9. Introduction to FEM

10. Application of FEM in structural analysis using ANSYS software

11. Problems solved in ANSYS (step-by-step guides)

12. The use of ANSYS for the formulation and solution of various types of finite element problems

practical teaching

FEA & ANSYS Mechanical APDL

1. ANSYS Mechanical Basics
2. General Analysis Procedure
3. Creating the Solid Model and the Finite Element Model
4. Defining Material Properties and Applying Loads
5. Solution Process
6. Postprocessing
7. Structural Analysis (2D and 3D examples)
8. Importing Geometry from CAD/CAM softwares
9. Producing Reports and Batch files

prerequisite

No specific requirements

learning resources

Handouts, Virtual classroom (Moodle), Powerpoint presentations, Computers with ANSYS software, Recommended literature and websites

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 3
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 30

references
A. Grbovic, Handouts, Faculty of Mechanical Engineering, Belgrade, 2012.
Alawadhi E., Finite Element Simulations Using Ansys, CRC PressINC, 2010.
Moaveni S., Finite element analysis: Theory and application with ANSYS, Pearson Prentice Hall, 2008.
Hibbeler, Structural Analysis, 6/E, Pearson Education, 2008

Warhead design and terminal ballistics

ID: MSc-1311
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
The main goal of the course is that students understand the importance, the basic concepts and methods of terminal ballistics and warhead mechanisms, as an integral part of the science of weapons systems. Students should understand the key ideas about the projectile/target interaction and their use in warhead design, as well as in design of ballistic protection.

learning outcomes
After successful completion of the course, students should be able to:

- define all types of projectiles/warheads action on targets,
- calculate the main parameters of all types of penetration processes,
- analyze the characteristics of blast effect,
- model the mechanisms of high-explosive projectiles fragmentation effect,
- analyze KE rod warheads,
- apply the experimental methods for determination of projectile efficiency parameters,
- understand the functional composition and the fundamentals of fuze design.

theoretical teaching
1. Scope of terminal ballistics

The effect of projectile on target. Types of projectiles. Types of targets. Tasks of terminal ballistics. Behavior of materials under dynamic conditions.

2. Penetration mechanics

Fundamentals of penetration mechanics. Armor piercing projectiles. Experimental determination of penetration. Long rod penetration. Shaped charge jet penetration.

3. Fragmentation

Mechanism of projectile fragmentation. Fragment velocity. Mass distribution of fragments. Experimental determination of the efficiency of fragmentation projectile.

4. Blast effect

Shock wave, pressure and impulse. Blast effect of projectiles. Underground explosion. Underwater explosion

5. Fuzes

Classification of fuzes. Functional composition of fuzes. Calculation of reliability and safety of fuzes. Testing of fuzes.

6. Fragmentation warhead principles

Naturally fragmenting warheads. Case expansion. Modelling average fragment mass. Geometric modeling. Control warhead fragmentation. Grid matrix.

7. KE rod warheads

Center core warhead design. Jellyroll warheads. Aiming KE rod warheads.

practical teaching
1. Approaches to solving problems in terminal ballistics

Examples of target kill probability. Models of material behavior under dynamic loads.

2. Penetration/Perforation

Simple penetration models penetration for thin targets. Penetration at high velocities.

3. Penetration/Perforation

Models of shape charge jet and long rod penetration.

4. Workshop - Preparation of the paper with a topic that is determined by arrangement with the student.

5. Fragmentation

Experimental evaluation of the efficiency of projectile fragmentation.

6. Blast effect

Determination of blast effect parameters.

7. Fuzes

Models of the effect of certain types of fuzes. Calculation of reliability and safety of fuzes.

prerequisite
Exams passed (preferred): Projectile design, Physics of explosive processes

learning resources
1. Jaramaz, S.: Warheads Design and Terminal Ballistics, Faculty of Mechanical Engineering, Belgrade, 2000.

2. Stamatovic, A.: Projectile design, Ivexy, Belgrade, 1995 (in Serbian)

3. Krsic, N.: Design of fuzes, VINC, Belgrade, 1986 (in Serbian)

4. Elek, P.: Manuscript for lectures, Faculty of Mechanical Engineering, Belgrade, 2010.

number of hours: 75

active teaching (theoretical): 30
lectures: 15
elaboration and examples (revision): 15

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Backman, M.E.: Terminal Ballistics, NWC China Lake, California, 1976.
Carleone, J.: Tactical Missile Warheads, Progress in Astronautics and Aeronautics, AIAA, Vol. 155, Washington, 1983.
Meyers, M.A.: Dynamic Behavior of Materials, Wiley-Interscience, 1994.
Elek, P., Jaramaz, S.: Penetration models for metal targets ans kinetic penetrators, Cumulative scientifical-technical information, Military Technical Institute, 2005, ISBN 978-86-81123-13-3, pp. 86
Elek, P., Jaramaz, S., Micković, D.: Fragmentation of the case od HE projectiles: Fragment mass distribution laws and physically based fragmentation models, MTI, 2011, ISBN 978-86-81123-23-2, pp.105

Weapon mechanics

ID: MSc-1407
responsible/holder professor: Jevtić T. Dejan
teaching professor/s: Jevtić T. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Detailed analysis of the influential parameters on the artillery weapons dynamics and construction solutions of artillery weapons individual elements. Study of design methodology for the artillery weapons mounting on the battle platform according to the forces transmitted to the platform. Practical implementation of calculations for basic structural elements of artillery weapon through the realization of projects.

learning outcomes
Mastering the calculation of forces that act on the individual pieces of the artillery weapon during firing cycle. Based on that, acquiring the ability of students to create their own software tool for the design of individual structural elements of artillery weapons. Students' ability to determine the mutual influence of weapon individual parts, as well as their complete influence on the weapon dynamics.

theoretical teaching
Consideration of different constructions of weapon carriage and their influence on the development of the force that acts on the battle platform. Conditions of the artillery weapon stability and immobility during the firing cycle. Study of different types of muzzle brake construction and determination of their efficiency. Design of recoil mechanisms (recuperator, hydraulic recoil brake, hydraulic counterrecoil brake, and fluid compensator). Design of different types of the cradle and consideration of the loads that occur during firing. Construction of the top carriage, bottom carriage arms, and equilibrators. Organization of the bore and outer surface of the weapon barrel. Basic concepts of autofrettage. Deformations and stress distribution of monoblock tube with autofrettage during firing. The main types and mechanisms of breechblocks and their characteristics. Influential parameters on the dynamics of the breechblock opening and cartridge case ejection. Design of breech rings and calculation of the stress distribution during the firing cycle.

practical teaching
Analysis of the influential parameters on the gun stability during firing. Muzzle brake efficiency and propulsion index. Calculation of threaded connection between the barrel and the muzzle brake. Forces that act on the recoil parts during recoil and counterrecoil. Recoiling parts velocity and travel change in time during recoil and counterrecoil. Calculation of the hydraulic brake force. Recuperator design and determination of the force that acts on the recoil parts. Dynamics of the breech block opening. Influential parameters on the cartridge case ejection dynamics. Deformations and stress distribution of monoblock tube with autofrettage during firing. Stress calculation of the breech ring.

prerequisite
There are no special conditions for attending the course.

learning resources
1. Micković, D.: Weapon mechanics - Handouts

2. G. Backstein, et al.: Handbook on weaponry, Rheinmetall GmbH, P.O.B 6609, D-4000 Düsseldorf

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 16
laboratory exercises: 0
calculation tasks: 2
seminar works: 0
project design: 10
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 8
colloquium, with assessment: 0
test, with assessment: 0
final exam: 7

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 60
requirements to take the exam (number of points): 35

references

Wind Tunnel Testing

ID: MSc-1158
responsible/holder professor: Peković M. Ognjen
teaching professor/s: Peković M. Ognjen
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: MFB

goals
Introduction to wind tunnel testing methodology. Introduction to specifics of various wind tunnel testings. Calibration, reduction and correction of measured data.

learning outcomes
Ability to organize wind tunnel measurements. Application of aerodynamic testing methodology. Ability to collect and reduce relevant data in wind tunnel measurement. Ability to apply correction and calibration procedures. Ability to design pressure, temperature, and force measurement systems. Ability to setup necessary wind tunnel parameters for specific measurements. Ability to implement and specify wind tunnel instrumentation. Ability to report and present measured data.

theoretical teaching
Wind tunnels and their design. Test section, calibration. Measurements of pressures, forces and moments. Type of balances and their calibration. Testing procedure. Wind tunnel corrections. Transonic wind tunnel measurements. Supersonic wind tunnel measurements. Non-invasive measurement methods. Processing of measured data.

practical teaching
Determination of flow field using PIV. Measuring of pressures, angularity. Measurement of forces and moments. Calibration of balances.

prerequisite
course in aerodynamics or fluid mechanics

learning resources
Wind tunnel, PIV, Pitot tubes, sensors, balances.

number of hours: 75

> **active teaching (theoretical):** 35
> lectures: 30
> elaboration and examples (revision): 5
>
> **active teaching (practical):** 35
> auditory exercises: 0
> laboratory exercises: 0
> calculation tasks: 15
> seminar works: 15
> project design: 0
> consultations: 5
> discussion and workshop: 0
> research: 0
>
> **knowledge checks:** 5
> check and assessment of calculation tasks: 0
> check and assessment of lab reports: 0
> check and assessment of seminar works: 5

check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 55
requirements to take the exam (number of points): 30

references
Pope A., Wind-Tunnel Testing, John Wiley and Sons, INC., New York, 1954
Pope A., High-Speed Wind Tunnel Testing, John Wiley and Sons, Inc., New York, 1965
Goethert B., Transonic Wind Tunnel Testing, Pergamon Press, Oxford, 1961
Tropea C., Yarin A., Foss John, Springer Handbook of Experimental Fluid Mechanics, Verlag Berlin Heidelberg, 2007

AEROSPACE ENGINEERING

Aeroelasticity

ID: MSc-0645
responsible/holder professor: Dinulović R. Mirko
teaching professor/s: Dinulović R. Mirko, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: aerospace engineering

goals
1. introduction to modern aeroelasticity problems and their analysis and practical methods to solving aeroelasticity problems in real aircraft structures

2. introduction to experimental dynamic analysis of aircraft structures

3. introduction to dynamics of thin walled structures

learning outcomes
After successful competition of the course students should be able to:

1. Determine forms of oscillation of thin walled structure

2. calculate the torsional divergence speed of lifting surface

3. Calculate the command reversal speed (ailerons) on the wings

4. Estimate flutter speed of the lifting surface using Teodorsen method

5. Generate finite element models of lifting surfaces of the aircraft for static and dynamic aeroelastic analysis .

theoretical teaching
In the theoretical part of the course following topics are covered: Introduction to aeroelasticity. Types of aeroelastic phenomena on aircrafts and structures in general. Static, dynamic aeroelasticity. Differntial equations and solution methods. Galerkin's method, collocation at the point, collocation at subdomain. Oscillations, types, mathematical models. Wing divergence, Command reversal, Flutter. Oscillations of continual distributed mass.

practical teaching
During practical part of the course covered topis in theoretical part are demonstrated in practice. Typical practical problmes are analyzed through numerical examples. Students are required to complete practical project work using computer modeling and analysis. All required material is available in the form of lecture notes, books and past exams and tests.

prerequisite
Mathematics, Resistance of materials

learning resources
Computing Laboratory for Theory of elasticity and Aeroelasticity

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 10
> laboratory exercises: 0

calculation tasks: 5
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 40

references

An introduction to the theory of aeroelasticity, Y.C. Fung, Dover publication

Aircraft armement systems

ID: MSc-1082
responsible/holder professor: Simonović M. Aleksandar
teaching professor/s: Peković M. Ognjen, Svorcan M. Jelena, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
The study of this course is to ensure adoption of procedures and methods for problem solving related to aircraft armament calculations. Students will be capable of independently study aircraft rocket, bomber and firearms armament elements in order to obtain maximum effectiveness for the given conditions of application for each of these types of aircraft weapons. Particular attention will be faced towards development trends of modern aircraft armament.

learning outcomes
By mastering of the course curriculum student obtains following subject - specific skills:

- thorough knowledge and understanding of different types of aircraft weapons and their application

- calculation of air weapons characteristics and possibility of their integration into the aircraft with the use of scientific methods and procedures

- linking basic knowledge in mathematics, programming, mechanics and fluid mechanics and their application in design and calculation of aviation weapons and its integration;

theoretical teaching
-Introduction to aircraft armament field -Division and classification-Historical development-Development trends- Aircraft bomber armament - Determining the actual coordinates of the aim-Aerodynamic integration of bombs, carriers and aircraft - Underslung load influence on aircraft characteristics-Aircraft underslung load removal calculations- Trajectory stabilization-Determination of forces and moments on the underslung loads-Parachutes and braking devices-Aircraft missile systems-The basic components of missiles and their arrangement-Structure calculations and structure types-Slender bodies aerodynamic characteristics-Aerodynamic interference-Steering elements design features-Stability derivatives-Damping of the pitching and rolling-Firearms-Definition and division of firearms-The basic components and mechanisms-Determination of forces and loads-Dynamics and shock in the automatic mechanisms, equipment and parts-Existing solutions of integration-Depreciation recoil force in accordance with the construction of aircraft-Connections in aircraft-container system.

practical teaching
-Division and classification of aircraft armament-Aircraft bomber armament, air bombs classification -Aerodynamic bombs, carrier and aircraft integration-Stabilization path-Parachutes-Aircraft missile armament-Missile classification-Design characteristics-Aerodynamic schemes-The basic components of missiles and their rearrangement-Rocket structure and construction calculation -Aerodynamic interference-Steering elements design features-Stability derivative-Aircraft firearms- Firearms definition and division-The main components and mechanisms-Determination of forces and loads-Dynamics and shocks in the mechanisms-Existing integration solutions-Depreciation recoil force

prerequisite
There is no necessary requirement for attendance of Aircraft Armament.

learning resources

1. Jankovic S. Aerodinamika projektila, Faculty of Mechanical Engineering, Belgrade, 1979,КДА (in Serbian)

2. Additional materials (written handouts, problem setting, guidelines for problem solving), DVL

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Jankovic S. Aerodinamika projektila, Faculty of Mechanical Engineering, Belgrade, 1979,КДА (in Serbian)

Aircraft control and systems

ID: MSc-1079
responsible/holder professor: Petrović B. Nebojša
teaching professor/s: Ivanov D. Toni, Peković M. Ognjen, Petrović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: aerospace engineering

goals
Course goal is to introduce students to integrated flight control computer systems, their functions, structures and principles. Course topics enable students to gain detailed insight into modern integration of aircraft systems and its components in aircraft control.

learning outcomes
Upon course completion, students gain knowledge and understanding of existing aircraft integrated control computer systems. Course topics prepare students for studies of more advanced topics of aircraft control systems and further specialization in this area, or, in the case that they are oriented to other aeronautical fields to fully understand complex problems of aircraft control systems.

theoretical teaching
Functions and structure of integrated aircraft control computer systems; System components; Various type of aircraft control systems; Sensors, busses, processors; Displays; Actuators; Flight control systems; Autopilots; Stabilizators; Dynamic models of flight; Longitudinal and lateral dynamic models; Transfer functions; Autopilot synthesis; Autopilot structure; Short period approximation; Gust model; Control command model.

practical teaching
Practical teaching is related to presenting samples, analysis and discussion with students in the fields previously treated theoretically. System components. Various type of aircraft control systems. Sensors, busses, processors. Displays. Actuators. Flight control systems. Autopilots. Stabilizators. Dynamic models of flight. Longitudinal and lateral dynamic models. Transfer functions. Autopilot synthesis. Autopilot structure. Short period approximation. Gust model. Control command model. Simulation model of short period longitudinal motion. Longitudinal dynamic model of F-14. Dynamic model of short period dynamics controller for F-14. Hydraulic dynamic model of horizontal stabilizator for F-14.

prerequisite
Students must have corresponding semestar in which this subject is teaching.

learning resources
Oprema i Sistemi Letelica - Sistemi automatskog upravljanja leta, Janković J. (in Serbian)

Written handouts from the lectures.

Written handouts from auditory exercises.

Internet.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30

auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15

check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Aircraft Design

ID: MSc-1132
responsible/holder professor: Grbović M. Aleksandar
teaching professor/s: Grbović M. Aleksandar, Svorcan M. Jelena
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
This course aims to provide a comprehensive overview of the conceptual design of an aircraft. A holistic teaching approach is taken to explore how the individual elements of an aircraft can be designed and integrated using up-to-date methods and techniques. The course includes analyses of existing airplanes and assessments of their strong and weak points with the aim of selecting the optimum concept. Students are thought how to define basic geometric parameters of an aircraft, to select appropriate configuration and propulsion system, define loads and specific thrust/power. Performances and stability of the airplane are also covered.

learning outcomes
After attending all lectures and completion of projects students will be able to analyze, specify, and develop aircraft concept according to required performances and purpose. They will have the ability to define and select the optimal aerodynamic scheme and determine essential design parameters. Also, they will know how to design aircraft parts and components efficiently and to prepare documentation for manufacturing.

theoretical teaching
Definition of aircraft purpose and mission. Statistical analysis and definition of trends. Basic geometric parameters of the aircraft. Definition or selection of the propulsion system. Integration of propulsion, equipment, and avionics. Landing gear definition. Determination of aircraft loads and preliminary sizing of aircraft elements. Production technology, selection of standard elements, selection of materials. Properties of materials used in aircraft design. Static stability of the aircraft. Dynamic flight properties, flying qualities. Basic performances, special performances, takeoff, and landing. Cost of the project.

practical teaching
Practical work with lecturer serves to illustrate concepts through examples and to help students to complete their projects. After project completion students present their work to professors and other students of the department. Final grades depend on the quality of the finished projects, student's activity during the school year, and the quality of presentations. During practical work, students use object-oriented programming for statistical analysis of known aircraft, learn how to use mechanical computer-aided design software, learn how to use and develop instruments for experimental testing, write programs for machines with computer numerical control and create a presentation of their project work.

prerequisite
As defined by curricula of study program.

learning resources
SimLab laboratory, application VAZMFB (https://vazmfb.com).

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 55
final exam: 30
requirements to take the exam (number of points): 30

references
A. Grbovic, M. Milos: Software Tools in Design, Faculty of Mechanical Engineering, Belgrade, 2017
Handouts and presentations

Aircraft maintenance

ID: MSc-1081
responsible/holder professor: Petrović B. Nebojša
teaching professor/s: Bengin Č. Aleksandar, Grbović M. Aleksandar, Dinulović R. Mirko, Mitrović B. Časlav, Peković M. Ognjen, Petrašinović M. Danilo, Petrović B. Nebojša, Svorcan M. Jelena
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: aerospace engineering

goals
Within the course "Aircraft maintenance" students will gain basic knowledge concerning contemporary theories and praxes in the maintenance and revitalization of both military and civil aircrafts. Furthermore, a part of the course is dedicated to exploration of maintainability, reliability of fighting tenacity, as well as the basic structural characteristics of the system that are defined in the early stages of design and development of modern aircrafts.

learning outcomes
After mastering the curriculum, students will be capable of creative thinking and decision making in the domain of aircraft maintenance. By gaining sufficient theoretical and practical knowledge, they will be able to participate equally in a working team designing or maintaining the aircraft and to further improve important flight characteristics such as reliability, maintainability, fighting tenacity or durability (particularly in cases of forced landings).

theoretical teaching
Introduction. Basic assumptions in aircraft maintenance. Technical maintenance. Safety and reliability in air-traffic. Maintenance concept. Maintenance activities. Maintenance levels. Maintenance in an airline. Line maintenance. Quantitative indicators of maintainability. Mathematical models of aircraft maintenance. Economical working life of equipment and systems. Necessary spare parts. Optimal number of checks. Minimal total cost. Reliability, usability and time-to-failure of regularly maintained systems. Defining the interval of preventive maintenance of parts and systems. Maintainability prediction. Aero-technical safety. Maintenance technologies. Determination and control of aircraft condition.

practical teaching
Maintenance activities and levels. Airliners line maintenance. Probability distributions in maintainability and repairability. Maintenance cost optimization. Maintainability functions. Repairability functions. Maintenance period. Maintainability index. Safety indicator. Human activities indicator. Equipment availability factors: nominal, achieved and usable availability. Computational assignments derived from the course material. Maintainability prediction. Structural maintainability. Computational assignments. Diagnosis – nondestructive testing methods. Contemporary concept of aero-technical safety. Aircraft fighting tenacity. Aircraft vulnerability. Consultations.

prerequisite
No specified conditions.

learning resources
Rasuo, B, Aero-technical safety, Serbian Military Headquarters, Belgrade, 2004;

Rasuo, B, Aircraft manufacturing technology, Faculty of Mechanical Engineering, Belgrade, 1995;

Additional materials (handouts, assignments etc.)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 55
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Aircraft Performance

ID: MSc-0948
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Kostić A. Ivan, Mitrović B. Časlav, Peković M. Ognjen
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
Introducing students to the complex movement of aircraft in atmospheric flight. During the course will be studied the performance of the aircraft, i.e. will be studying the movement of the aircraft's center of gravity under the action of forces. Within the Course Term Project Assignment, that covers and integrates the entire course material, students will be able to obtain performance of the aircraft, individually with the use of modern software packages, such as Matlab, Mathcad, Excel, etc.

learning outcomes
Mastering the course, the student acquires enough theoretical knowledge to be able individually and creatively to define performance capabilities of modern aircraft and all restrictions that result from them. In this course, students will gain full sublimation and verification of previously acquired knowledge and skills they have acquired within the Aeronautical module from the group of aerodynamic courses.

theoretical teaching
Introduction. General assumptions in the calculation of the aircraft performance. Coordinate systems and coordinate transformation. Types of movement. The forces acting on the aircraft during the flight. Performance of the aircraft powerplants. Propellers. Geometric and aerodynamic characteristics of the propellers. Selection of the propeller. The equations of motion of aircraft. Basic aircraft performance. Basic flight performance (horizontal and vertical speed, time of the climbing, theoretical and practical flight ceiling). Special aircraft performance. Take off and landing. The effect of wind on the flight performance. Range and endurance, radius of action. The effect of wind on the range and radius of action. Unsteady movement in the vertical plane. Dive and pulling out of a dive. Aircraft maneuvers. Dynamic flight ceiling. Loop. Immelman. Roll. Pugachev's Cobra. Bell. Herbst maneuver. Optimization of the flight path of the aircraft. Spatial movement of aircraft. Introduction to the mechanics of cosmic flight.

practical teaching
Aircraft powerplant. Selection of the propeller. Aircraft powerplants performance. Estimating of the basic aircraft performance. Estimating of the airplane special performance. Calculation of the range and endurance. Estimating of movement in the vertical plane. Aircraft gliding. Gliding airspeeds polar curve. Calculation of dive. The maximum dive speed. Calculation of the pulling out of a dive. Load factor in pulling out. Calculation of the sudden pitch and jumping of the aircraft. Calculation of dynamic ceiling. Calculation of the loop, Calculation of aircraft turning flight. Slipping turn. Banked turn (steady coordinated turn). Banked turn with slipping. Limitations of the turn performance. Combat turn. Extreme flight regimes. Flight at high angle of attack and spin. Maneuvering flight envelope. Extreme flight regimes. Consultations.

prerequisite
Required: Aerodynamic design

learning resources
Books, Maido Saarlas, Aircraft Performance, John Wiley & Sons, Inc,Hoboken, New Jersey, 2007, include necessary material for lectures, exercises, assignments, projects and term papers.Require additional

materials (handouts, setting assignments, term papers, etc..) Are given at the web site or reproduced on paper. Large-scale electronic materials can be made available to students in direct contact.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 45
final exam: 30
requirements to take the exam (number of points): 35

references

Aircraft propulsion

ID: MSc-1266
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Davidović S. Nikola, Ivanov D. Toni, Mitrović B. Časlav, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
The main goal of the subject is to explain to the student the working principles, types, base elements, characteristics and working areas of air-breathing engines. All the time there is strong connections between types of engines and types of aircraft's which combination graves best overall performances.

learning outcomes
The student gets ability to analyze and synthesize entity of flying vehicle and propulsor. The student gets knowledge of various types of air breathing engines, and their main energetic components. The student gets knowledge of engine performances, on which bases can have real proposition of the engine quality. Reached knowledge is good base for ongoing studies.

theoretical teaching
Thermodynamic cycles and thrust. Propulsion efficiency and basic engine performances. Propulsion circle and its basic elements. Ideal ramjet, turbojet, turbojet with afterburner and turboshaft engines. Ideal turbofans with separate and common nozzle.

Real elements of propulsion circle: intake, and nozzle. Compressor and turbine. Mixer, combustion chamber and afterburner. Working lines of turbojet and turboshaft engines. Engine starting. Engine performances: altitude, speed and throttling. Working envelops of various engine types. Actual problems in airbreathing propulsion and future trend.

practical teaching
Practical part of the subject consists: working of numerical problems, solving of conceptual problems, discussions and explanations within presents of real engine cross section.

prerequisite
-

learning resources
Handouts, textbook, various tables needed for numerical examples, turbojet engine cross section.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 20
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 50

references
Mechanics and Thermodynamics of Propulsion - Hill & Peterson 1992
Aerothermodynamics of Gas Turbine and Rocket Propulsion - G. Oates 1984
Aircraft engine design Matinglly 2002

Applied Aerodynamics

ID: MSc-0946
responsible/holder professor: Kostić A. Ivan
teaching professor/s: Bengin Č. Aleksandar, Kostić A. Ivan, Kostić P. Olivera, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
The course objective is that students develop an understanding of practical applications of subsonic aerodynamics and to provide an introduction to compressible flows (lower transonic domain). The course initially covers concepts of airfoil theory, and the analysis of symmetric and cambered airfoils using analytical and numerical tools. The course also covers wing theory, lifting-line theory, elliptic wings, twisted wings, and their practical applications in the design of wings to meet the assigned aerodynamic requirements. Finally, students are involved in practical calculations of aerodynamic characteristics (lift, drag and the derived parameters) of the entire aircraft in configurations for take-off, landing and cruising flight in subsonic and lower transonic speed domains.

learning outcomes
After accomplishing the course, students should be capable of understanding and explaining various aspects of the relations between the body shape (airfoil, lifting surface, air vehicle) and its aerodynamic characteristics. In addition, the students must be able to recognize the opportunities for the application of the acquired knowledge for the solution of different, both aeronautical, and non-aeronautical practical problems.

theoretical teaching
In the theoretical part of course the following topics are analyzed. Two-dimensional problems: airfoil characteristics: the method of singularities, thin airfoil theory, method of droplets, panel methods, empirical methods and the determination of aerodynamic loads. Three-dimensional problems: vortex wing models, the theory of lifting line, analysis of elliptic wing, twisted non-elliptic wings, influence of geometric parameters on aerodynamic characteristics, loading of wings of arbitrary shape. Aerodynamic characteristics of complete aircraft. Wing airfoils selection, lifting characteristics and drag of wing and complete aircraft in take-off and landing configurations, and in cruising flight at subsonic and lower transonic speeds. Role of the CFD in the analysis and determination of aerodynamic characteristics.

practical teaching
In the practical part of the course professor demonstrates the numerical examples in various areas. Practical work of students is accomplished through a virtual laboratory, available 24 hours (program MOODLE). In the workshop students have access to the professor's lectures (handouts), assignments for practice and tests. Practical training includes the preparation of project (calculations of aerodynamic characteristics of a selected aircraft). Project is performed by each student individually.

prerequisite
None. Students who did not take any of aerodynamics courses on bachelor studies are referred to the additional handouts by professor.

learning resources
This course has a virtual classroom on the Internet. At the first lecture students are enrolled and trained for work in Moodle software package. In the workshop, students have access to lectures and exercises, guidelines for project design, internet resources, etc.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 5
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 25

references
I. Kostić, Handouts in Applied Aerodynamics, University of Belgrade, Faculty of Mechanical Engineering, Belgrade 2014.

Avionics

ID: MSc-0311
responsible/holder professor: Petrović B. Nebojša
teaching professor/s: Vorotović S. Goran, Peković M. Ognjen, Petrović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: aerospace engineering

goals
Objectives of the course are to introduce students to aviation electronic equipment and systems, their functions, structures and basic principles. The subject should provide students a detailed a detailed view of the latest trends in avionics technology and development.

learning outcomes
Successful completion of course students acquire the ability to understand the existing solutions aviation electronic equipment and systems.The student acquires knowledge about the structures of various types of avionics equipment and systems. The knowledge that allow students to opt for other aviation issues to understand the electronic aviation equipment and systems,and for those who want to specialize in these issues are fundamental to the acquired knowledge for further work.

theoretical teaching
Avionics elements,AS 15531/MIL-STD-1553B, ARINC 429.Commercial standard digital bus. Head-Up displays, Head-mounted displays. Flight deck design.Batteries, Characteristcs, Types. Avionics functions.Fly By Wire-Electrical flight controls, system architecture, modes of the system, pitch control, roll control, yaw control, failure detection. Navigation and Communications, sattelite communications and navigation systems, ATC. Flight management systems, automatic direction finding, distance measuring equipment, TACAN. Visualization. Traffic collision an Avoidance system. Instruments landing system. Certification of civil avionics. Software, Ada, RTCA DO-178B/EUROCAE ED-12B. Implementation, B-777,A330/340,MD-11,F-22

practical teaching
Practical work includes the presentation of examples, analysis and discussion with students in areas that were previously presented theory. Avionics elements, AS 15531/MIL-STD-1553B, ARINC 429. Commercial standard digital bus. Head-Up displays, Head-mounted displays. Flight deck design. Batteries, Characteristcs, Types. Avionics functions. Fly By Wire-Electrical flight controls, system architecture, modes of the system, pitch control, roll control, yaw control, failure detection. Navigation and Communications, sattelite communications and navigation systems, ATC. Flight management systems, automatic direction finding, distance measuring equipment, TACAN. Visualization. Traffic collision an Avoidance system. Instruments landing system. Certification of civil avionics. Software, Ada, RTCA DO-178B/EUROCAE ED-12B. Implementation, B-777,A330/340,MD-11,F-22

prerequisite
The condition of attending the course is student enrollment in the semester in which this subject is taught.

learning resources
Written sources from the lecture.

Written sources from the auditory exercises.

Civil Avionics Systems,I.Moir and A.Seabridge

Intelligent piezo actuators, N. Petrovic

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
The Avionics Handbook, Cary R. Spitzer

Bionics in Design

ID: MSc-1080
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: project design
parent department: aerospace engineering

goals
Introducing students to the process and the procedure of synthesis (create) a combination of mechanical systems engineering design (design) and industrial and bionic design. Besides, the goal of this course is to develop creative skills of students in the design of machines. Understanding the methodology and procedures to create innovative mechanical system through the phase of designing, selection of parameters, dimensions and shape of machine parts, alignment features (functional and aesthetic) with the environment, living and working environment.

learning outcomes
The student is introduced to the procedure of abstract thinking and creative idea generation,the development methodology of the new principal, conceptual, based on bionic solutions.Dressed in designing machine parts and assemblies based on bionic principles, functional, technological, aesthetic, ergonomic, and others. Trained to implement budgets for the mutual adjustment of parameters of machine parts with the limitations, the development of forms and sizes.

theoretical teaching
History and Development bionic system. Experience in engineering: flying, navigation, civil engineering, architecture, and military construction. Inclusion bionic aspects in the design process and construction of mechanical systems. Mathematical principles of bionic system. Fibonacci sequence. Fibonacci spiral. "Gold" section (the relationship) and "Golden" angle. The influence of the golden ratio in engineering design. The concept of fractals and fractal geometry. Cantor set. Euclid’s natural forms. The effects of scale, form and similarity in nature and their impact on the development of modern machine design and systems. Energy efficiency of natural systems as models in the design of modern engineering structures, the experience of flight, navigation, energy, process engineering, military technology and others. Natural (bionic) building materials. Modern composite materials. Thermoplastic and thermosetting materials in engineering. "Smart" and functional materials in engineering structures and modern design.

practical teaching
Influences Leonardo da Vinci, Sir George Cayley, Otto Lilienthal, Gustave Eiffel, Raoul France and Graf von Zeppelin. Bio-strategy application process in fulfilling the spirit of laws rules of biological evolution, which should translate into an acceptable technical solution. Ten basic principles of natural structures. Implementation bionic humanoid proportions and impact on the ergonomic design. Some typical relations (numbers) that characterize the specific effects of similarity and scaling in nature. Bionic Design - views and role models. Wood, vegetable fiber, animal: wool, silk, spider web, etc.. Natural resins. Artificial resins - matrix (binder) materials: Epoxy, Polyester, Vinyl ester, phenolic, polyimide, bismaleimide et al. Cellular materials, and intelligent optical fiber. Electrical and magnetic reostatic. Semiconductor spintronics. Magnetic materials. DNA nano-products.

prerequisite
No special requirements

learning resources
Laboratory for Design in Mechanical Engineering, Books, Werner Nachtigall, Biologisches Design, Springer-Verlag Berlin Heidelberg 2005, include necessary material for lectures,exercises, assignments, projects and term papers. Require additional materials (handouts,setting assignments, term papers, etc..) Are given at the web site or reproduced on paper. Large-scale electronic materials can be made available to students in direct contact.

number of hours: 30

active teaching (theoretical): 10
lectures: 8
elaboration and examples (revision): 2

active teaching (practical): 10
auditory exercises: 4
laboratory exercises: 0
calculation tasks: 0
seminar works: 4
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 55
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Composite Structures

ID: MSc-0639
responsible/holder professor: Dinulović R. Mirko
teaching professor/s: Dinulović R. Mirko, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: aerospace engineering

goals
1. introduction to modern approach in stress analysis of composite material structures on aircraft, it's application to practical problems solutions as well as experimental methods applied to structural verififcation of composite structures.

2.Introduction to specifics of thin walled structures and application of composite materials for these structures.

3.Introduction to computer simualtion and stress analysis of composite structures on aircrafts.

learning outcomes
1. Starting from the mechanical properties of fibers and matrices to calculate the properties of the composite elastic lamina .

2. calculate the load capacity of the composite lamina applying the HILL, Wu and Tsai criteria

3. Using classical laminate theory (CLT) determine stress strain state in composite laminate for a given external load

4. use commercial software for calculation of strength of aircraft composite structures

theoretical teaching
Basic Definitions. Polymer Matrix and fiber characteristics. Prepregs. Fabrication processes. Autoclave polymerization. Characteristics of composite materials. Elastic stres-strain behavor of composite materials modeling. Plane stress. Principal stresses, principal deformations. Temperatre deformations. Deformations in respect to humidity. Failure Criteria applicable to composite media. Kirchoff and Midlin plate theories. Effective mechanical characteristics of laminates. Composite Beams. Interlaminar stresses. Composite buckling. Delamination, structural analysis of composte material constructuctions using finite element method.

practical teaching
In the practical part of the course, stress-strain theory applicable to composite media is demonstrated. Real practical problems are analyzed. Practical work is carried out using computers and finite element analysis software for composite materials structures. Students are provided with all necessary materials in the form of lecture notes, books and past exam and test papers.

prerequisite
Recommendation: Theory of elasticity, Strucural analysis of aircraft structures

learning resources
Course notes in electronic form, media materials, computer simulation models available after class, internet resources.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 40

references
Engineering Mechanics of Composite Materials, D.Ishaii
Composite Airframe Structures, Michael Chun-Yung Niu , Michael Niu

Computational Aerodynamics

ID: MSc-1078
responsible/holder professor: Simonović M. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Peković M. Ognjen, Svorcan M. Jelena, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: aerospace engineering

goals
The goal of the course is to train students in modeling flow problems. After attending the course, finishing all exercises and giving the final presentation, students should be able to recognize the type of the problem, formulate necessary boundary and initial conditions, choose an appropriate discretization scheme and write a program for calculating flow inside or around simpler geometric shapes, such as a nozzle or an airfoil.

learning outcomes
By successfully adopting the program of the course, a student: acquires theoretical knowledge sufficient to recognize the type of the problem as well as the type and number of additional conditions necessary to completely and uniquely define the problem that is being simulated; recognizes basic approximation schemes of the typical problems; masters the principles and foundations of programming related to simulations of continuum; observes the structure of the simulation software that consists of pre-processing, simulation and visualization.

theoretical teaching
Derivation of the transport equation and its application to the basic laws of the fluid flow. Finite difference and finite volumes approximations of the partial differential equations. Basics of the generation of computational grids and their classifications. Transformation of the Navier-Stokes equations in general curvilinear coordinate systems. Metrics calculation and simplification of the boundary layer equations and parabolic Navier-Stokes equations. Computation of the Navier-Stokes equations for thin viscous layers. Approximation, boundary and initial conditions formulation, computation algorithm of direct numerical simulations. Compressible inviscid flow presented by an approximation of the Euler equation. Calculation of the transformation metrics for general curvilinear coordinate systems. Basics of turbulent flows modeling.

practical teaching
Practical training accompanies materials presented during theoretical lectures. In the beginning, students are registered and they familiarize with working in Linux operating system. After that, illustrative examples are completely presented starting with the problem formulation, presentation of the appropriate equations and their approximation, stability and convergence studies, code and reading of the necessary input data, finishing with presenting solutions graphically. Students solve their homework independently and present it to their colleagues.

prerequisite
Defined by the curriculum of the study program/module.

learning resources
1. KPN

2. KLR

3. MPI software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 55
final exam: 30
requirements to take the exam (number of points): 25

references

Petrović Z. Stupar S., Computer design, Faculty of Mechanical Engineering, 1992, KPN(in serbian)

Flight Dynamics

ID: MSc-0949
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Bengin Č. Aleksandar, Kostić A. Ivan, Mitrović B. Časlav, Peković M. Ognjen
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
The main objective of the course is to develop understanding of the stability and controllability of the aircraft. This course directly prepares student to apply knowledge of the stability, maneuverability and aircraft control in the design of the aircraft. Within the project assignment that encompasses and integrates the whole curriculum, the students will be able to fully master the analysis of stability and maneuverability in the design of aircraft by using modern software packages.

learning outcomes
Having mastered the planned curriculum, the student acquires sufficient theoretical knowledge to be able to independently define the state of the static and dynamic stability and maneuverability of modern aircraft and any flight restrictions that arise from it. In this course, students will receive full sublimation and the verification of previously acquired knowledge and skills that they have required within the aviation modules from the group of aerodynamic subjects.

theoretical teaching
- Introduction.
- Revision of mechanics of aircraft flight.
- Basic concepts of stability and controllability of the aircraft.
- Differential equations of stability.
- Stability criteria.
- Aerodynamic stability derivatives.
- Static stability and controllability of the airplane.
- Dynamic stability and controllability of the aircraft.
- Aircraft parts contributions to the longitudinal stability (wings, horizontal tail, fuselage and nacelle contributions).
- Power plant influence on the longitudinal static stability.
- Neutral point of the aircraft.
- Angle of horizontal stabilizer setting.
- Balancing with the deflection of elevator.
- Marginal rear and front position of the aircraft centre of gravity permitted.
- Longitudinal static stability of the aircraft.
- Static stability of the aircraft in maneuvering flight.
- Lateral static stability and maneuverability of the aircraft – Dihedral effect.
- Dynamic stability of the aircraft.
- Longitudinal dynamic stability.
- Lateral-directional dynamic stability.

practical teaching
Criteria of stability and controllability of the aircraft movement. Calculation of the certain aircraft parts contribution to the total longitudinal stability with the control held. Rear position of the centre of the aircraft gravity. Calculation of the longitudinal controllability of the aircraft. Calculation of the longitudinal static stability with the control released. Calculation of forces acting on the stick in steady

flight. Calculation of the longitudinal static stability in maneuvering flight with the control held. Calculation of the longitudinal static stability in maneuvering flight with the control released. Derivatives and parameters in the equations of the aircraft motion. Experimental determination of stability derivatives. Computation tasks from the contents taught in the course. Tutorials follow the theoretical lectures. Consultations.

prerequisite
No special conditions

learning resources
Basic material: Č. Mitrović – Flight Dynamics (handouts) and instructions for project assignment (handouts).

Necessary material for lectures, tutorials, assignments, projects and term papers will be available to the students on the following website http://vaz.mas.bg.ac.rs/moodle.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 10
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 10
calculation tasks: 10
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 35

references
C. Mitrovic - Flight Dynamics (handouts) and instructions for the preparation of Terms of Reference (handouts)
M. Nenadović, The stability and maneuverability aircrafts, I and Part II, Belgrade (1981/1984)
Jan Roskam, Airplane Flight Dynamics and Automati

Helicopters

ID: MSc-1131
responsible/holder professor: Simonović M. Aleksandar
teaching professor/s: Svorcan M. Jelena, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: aerospace engineering

goals

1. Introduction to rotary lifting surface vehicles.
2. Introduction to rotor aerodynamic theory.
3. Design of helicopters.
4. Performance of helicopters.

learning outcomes

1. Understanding of aerodynamic VTOL schemes.
2. Selection of the aerodynamic scheme in helicopter design.
3. Mastering theoretical foundations of rotary wing aerodynamics.
4. Ability to calculate aerodynamic and performance characteristics of the helicopter.
5. Ability to design rotor blade.
6. Ability to conceptually design helicopter.
7. Ability to apply modern software tools in design of helicopters.
8. Ability to optimize helicopter design parameters.

theoretical teaching

In theoretical part the following is taught: VTOL aircraft, Theory of ideal rotor, Blade element theory, horizontal flight of a helicopter, vertical flight performances, horizontal flight performances, Stability of a helicopter, design schemes of a helicopter, helicopter control, Design of rotor blade. EASA regulaations for helicopter and transmission design.

practical teaching

Theory is applied to chosen helicopter. Practical work of the student is monitored by MOODLE. Lectures are downloaded using online access. Homework and other materials to master lectures are supplied. Students do projects in a group and finally present results to other students.

prerequisite

Suggested: Aerodynamic design

learning resources

Lectures in electronic form. Simulations and movies are accessible via MOODLE and internet.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 10
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 55
project design: 0
final exam: 30
requirements to take the exam (number of points): 25

references
J. Gordon Lishman, Principles of Helicopter Aerodynamicss, Cambridge Universithy Press
A. R. S. Bramwell, Helicopter Dynamics, Edvard Arnold,, 1976
J. Seddon, Basic Helicopter Aerodynamics, BSP Professional Books, Oxford, 1990

High Speed Aerodynamics

ID: MSc-0950
responsible/holder professor: Kostić A. Ivan
teaching professor/s: Bengin Č. Aleksandar, Kostić A. Ivan, Kostić P. Olivera, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals
The aim of this course is to introduce students to basic concepts of high speed aerodynamics. Emphasis is given to transonic and supersonic flow problems. External flows (supersonic airfoils, wings and complete aircraft lifting configurations) and internal flows (supersonic intakes, nozzles and diffusers).

learning outcomes
Upon completion and passing the course the student should be capable of understanding the basic concepts and problems in the field of aerodynamics at transonic and supersonic speeds. It is expected that the student knows how to apply the acquired knowledge in this field to solve practical engineering problems.

theoretical teaching
The theoretical part of the course covers the following topics: Classification of flow and flow model (Navier-Stokes equations, the Euler, the potential of small disturbances, Prandtl-Glauert and Laplace). Singularities and discontinuities in the flow field. The method of characteristics and conical flow field. Airfoil in transonic and supersonic field (linear airfoil theory and the theory of higher order). Wing in supersonic flow (influence of tips, sweep, delta wing, supersonic and subsonic leading edge). Computational analysis of complete aircraft lifting configurations in transonic and supersonic flow fields. Intakes, nozzles and diffusers.

practical teaching
Practical part of course demonstrates numerical examples in all areas. Practical work of students is accomplished through a virtual classroom, available 24 hours (program MOODLE). In the workshop students have access to the professor's lectures (handouts) and tests for practice. Practical training includes preparation of three projects. Each student works individually, and student qualifies for the final exam after completing at least two of the three projects.

prerequisite
Attended course in Applied Aerodynamics, or a course in fluid mechanics which provides satisfactory background knowledge (with professor’s approval).

learning resources
The students have access to the virtual classroom on the Internet. At the first lecture students are enrolled and trained for work (Moodle software). In the workshops students have access to the lectures and exercises, guidelines for project preparation, internet resources, etc.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5

seminar works: 0
project design: 5
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 25

references
R.T.Jones: High Speed Wing Theory, Princeton University press, 1999.
H.Ashley: Aerodynamics of Wings and Bodies, McGraw Hill, 1995.

Project Management & Air Regulation

ID: MSc-0142
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Mitrović B. Časlav, Petrović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: aerospace engineering

goals
Course objective

• Understanding the importance of project management in aviation.

• The creation, introduction and use of aviation projects.

• Determining the functionality of your own projects.

• Preparation, analysis and project management.

• Understanding and preparing the necessary documents for the implementation of projects.

learning outcomes
The acquired knowledge enables the student to:

• Prepare, create and show their own skills,

• Determine the functionality of the aviation project,

• Prepare, perform and manage the development of the aviation project,

• Determine technology of designing an aviation project,

• Recognize the requirements of the local aviation industry in projects,

• Make the necessary documentation of aviation project,

• Implement and collect aviation project.

theoretical teaching
MODERN APPROACHES IN DESIGN (feasibility study, the methodology of improvement, modeling)

Project management (requirements, quality, time, cost, standards)

IMPLEMENTATION OF PROJECTS (initialization, implementation, monitoring and control, cost efficient)

SPECIFICS IN AIRCRAFT DESIGN (strategy in the region; aviation terminology)

WEIGHT AND PERFORMANCE REQUIREMENTS (zones on the aircraft, the speed limit requirements; flight performance)

Aviation law (aviation regulations, certification, airworthiness)

REGULATIONS REGARDING SECURITY (human factors, safety precautions,emergency procedures)

REGULATIONS OF MONITORING AND FLIGHT (planning, defining and tracking the flight operations manual, flight plan revision)

PRACTICAL CONSTRUCTION PROJECT (information gathering, development,simulation of project)

practical teaching
Parameter identification and selection of software for designing. Determination of technology and pricing of the project. Defining the requirements of aircraft weight and performance. The requirements in terms of technological and structural concepts of the aircraft. Aviation security. Aeronautical terminology. Development of wind rose. Speed limit requirements. Aerodynamic design of aircraft performance and sizing, performance requirements takeoff, landing and the other flight regimes. Category airworthiness of the aircraft. Analysis of air regulations. Application of CAD technology. Define data visualization. Defining the contours of the aircraft. The design of the aircraft. Modeling of aircraft structure. Systematization of documentation. Research on aircraft accidents. Analysis of the project.

prerequisite
'defined curriculum of study program / modules'

learning resources
To cope with the case, it is necessary the use of textbooks, manuals for the project, a handout, Internet resources. IT equipment (hardware, CAD workstations, software (CAD, SSO, RRO) pcs. Equipment) ICT, available in the laboratory Aerotechnical Institute).

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 10
calculation tasks: 0
seminar works: 5
project design: 15
consultations: 0
discussion and workshop: 4
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references

Č. Mitrovic, Aviation regulations, textbook in preparation, full color, A4 format, Faculty of Mechanical Engineering
Air Law , JAA - Joint Aviation Authorities, Theoretical Training Manual, Oxford, 2004
European Aviation Safety Agency, Certification Spec

Rocket Motors

ID: MSc-1383
responsible/holder professor: Davidović S. Nikola
teaching professor/s: Vorotović S. Goran, Davidović S. Nikola, Ivanov D. Toni, Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: aerospace engineering

goals
Introducing students with rocket motor with solid and liquid propellant. Students are introduced with different types of rocket motors, their theoretical basis and performances. Experimental part consists of engine test demonstration and determination of burning velocity of rocket motor with solid propellant.

learning outcomes
By mastering the curriculum a student gains specific skills:

-knowledge and understanding of rocket motors
-calculation of rocket motor performances
-design of geometry of propellant grain of solid rocket motor

theoretical teaching
• Area of application of rocket motors
• Types of rocket motors and method of functioning
• Performances of ideal rocket motor
• Processes in combustion chamber and nozzle
• Real performances of rocket motor with solid propellant
•Determination of parametric dependence of burning velocity of rocket motor with solid propellant
• Design methodology of rocket motor with solid propellant
• Selection criteria of pressure in combustion chamber
• Basic shapes of propellant grain
• Internal ballistics of rocket motor with solid propellant
• Determination of analytical expression for heat flux at combustion chamber and nozzle
• Heat transfer and thermal protection
• Physical model of erosive burning
• Rocket engines with liquid propellants (characteristics, design and performances)

practical teaching
• Area of application of rocket motors
-Analysis of application of jet motors
• Types of rocket motors and method of functioning
-Analysis of chosen world rocket motors
• Performances of ideal rocket motor
-Numerical example of calculation of performances of ideal rocket motor
• Processes in combustion chamber and nozzle
-Numerical example of calculation of processes in combustion chamber and nozzle
• Real performances of rocket motor with solid propellant
-Numerical example of calculation of performances of real rocket motor
•Determination of parametric dependence of burning velocity of rocket motor with solid propellant
-Demonstration of rocket motor with solid propellant test. Analysis of test data and determination of burning rate law.

• Design methodology of rocket motor with solid propellant
-Seminary work: Design of rocket motor with solid propellant
• Selection criteria of pressure in combustion chamber
-Seminary work: Design of rocket motor with solid propellant
• Basic shapes of propellant grain
-Seminary work: Design of rocket motor with solid propellant-choice of geometry of propellant grain
• Internal ballistics of rocket motor with solid propellant
-Seminary work: Design of rocket motor with solid propellant-internal ballistics
• Determination of analytical expression for heat flux at combustion chamber and nozzle
-Seminary work: Design of rocket motor with solid propellant-heat transfer
• Heat transfer and thermal protection
-Seminary work: Design of rocket motor with solid propellant-calculation of nozzle wall temperature
• Physical model of erosive burning
-Seminary work: Design of rocket motor with solid propellant-erosive burning rate

prerequisite
There are no necessary conditions for attending the subject.

learning resources
1.Manual for design of Sounding rockets, Part 2, B.Jojic, Dj. Blagojevic, A.Pantovic, V.Milosavljevic

2.Additional materials (lecture hand-writings)

3.Jet Propulsion Laboratory of EDePro company, Belgrade

4.Commercial software for calculation for rocket motor performances

number of hours: 75

active teaching (theoretical): 35
lectures: 30
elaboration and examples (revision): 5

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 10
calculation tasks: 5
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 20
calculation tasks: 0

seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 25

references

В.Е. Алемасов, Дрегалин А.Ф,Theory of Rocket Motors
Баррер М., Rocket Motors
Dieter T. Huzel, David H. Huang, Design of Liquid propellant rocket engines
Фахрутдинов И.Х., Котельников А.В., Construction and design of Solid propellant rocket motors

Skill Praxis M - VAZ

ID: MSc-1216
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Dinulović R. Mirko, Petrović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: oral
parent department: aerospace engineering

goals
Practical experience and stay in environment in which the student will realize his professional career. Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of an mechanical engineer in such a business system.

learning outcomes
Student gets practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, within the context of his future professional competence. Establish the personal contacts that will be able to use in further education, or entering into future employment.

theoretical teaching
-

practical teaching
Practical work involves working in organizations that perform various activities related to mechanical engineering. Selection of thematic areas and commercial or research organizations carried out in consultation with the concerned teacher. Generally, a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations concerned with maintaining mechanical equipment, and public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice may also be made abroad. During practice, students must keep a diary in which to enter a description of the tasks performed, the conclusions and observations. Following the practice must make a report to defend the subject teacher. The report is submitted in the form of the paper.

prerequisite
There aren't any compulsory conditions for course attendance.

learning resources
Resources available at the place of professional practice.

number of hours: 90

active teaching (theoretical): 0
lectures: 0
elaboration and examples (revision): 0

active teaching (practical): 80
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 80
project design: 0
consultations: 0

discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 10

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 70
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Structural Analysis

ID: MSc-0947
responsible/holder professor: Petrašinović M. Danilo
teaching professor/s: Grbović M. Aleksandar, Dinulović R. Mirko, Petrašinović M. Danilo
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: aerospace engineering

goals

1. Introduction to problems and modern calculation methods in stress analysis of aircraft structures, as well as their application to solving real problems.

2. Introduction to experimental stress analysis of aircraft structures.

3. Introduction to thin walled structures and composite materials.

4. Introduction to modern computational methods for stress analysis related to airframe structures.

learning outcomes

1. Mastering basic structural analysis theories.

2. Application of theoretical knowledge to solve practical problems.

3. Understanding the basis of aircraft design process.

4. Understanding modern methods in structural analysis for stress analysis of aircraft structures.

theoretical teaching

In the theoretical part of this course following topics are presented: Variational principle. Principle of virtual work. Minimum energy principle. Rayleigh-Ritz method. Galerkin Method. Collocation method. Finite element method formulation. Convergence criteria. Finite element formulation for rods and beams. Stiffness matrices and equivalent force matrices. Finite elements for plane stress and plane strain, axial symmetric and volume finite elements. Automatic mesh generation. Finite elements software. Elastic material models. Real structures modeling. Element selection. Mesh density selection.

practical teaching

Substructure modeling. Substructure interaction. Thermal stresses. Initial deformations. Residual stresses. Non-linear models for constitutive equations. Solution methods. Large deformations and large rotations tensor. Stress tensor formulation for large deformations. Local and global problems in stability analysis. Methods for solving non-linear problems. Results analysis. Adaptive meshes. Structure optimization. Quasi-static and dynamic problems.

In practical part of the course, previous theories are demonstrated in real applications. Numerous problems are analyzed. Practical student work is carried out through mandatory exercises using computers for modeling and analysis. Practical part of the course also includes the visit to the laboratories for static and dynamic experimentation of the VTI institute.

prerequisite

Recommended: Theory of elasticity, Structural Analysis of Flying Vehicles

learning resources

Handouts in e-format, demonstration films and computer simulation, Internet resources, application VAZMFB (https://vazmfb.com).

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 40

references
Introduction to Aircraft structural Analysis, T. Megson
Structural Analysis with Finite Elements, Hartmann
Concepts and Applications of Finite Element Analysis, 4th Edition, Cook, Markus and Plesha

Wind Turbines 2

ID: MSc-1130
responsible/holder professor: Svorcan M. Jelena
teaching professor/s: Ivanov D. Toni, Peković M. Ognjen, Svorcan M. Jelena, Simonović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: aerospace engineering

goals
The course provides an overview of key aspects in wind energy engineering as well as design principles of wind turbines. Throughout the course the student will be acquainted in detail with the most fundamental disciplines of wind energy research such as: wind measurements and resource assessment, possible wind turbine designs and their modeling, aerodynamics, structural mechanics, wind turbine manufacturing technology and materials, electrical systems etc, which will be realized through the use of different, simpler analytical, empirical and numerical methods.

learning outcomes
The student will gain a rational understanding of wind energy engineering and different wind turbine concepts and design methods.

Through hands-on exercises, the student will learn to perform wind energy calculations based on simple models.

Working with the different course disciplines (applied mathematics, programming, CFD, structural mechanics, optimization, manufacturing technologies) will enable the student to identify the most interesting and/or relevant aspects of wind energy engineering to be pursued in his/her future studies or professional career or applied on similar structures (propellers, helicopter rotors).

theoretical teaching
- Introduction to wind energy

- Wind resources (wind speed variability); Test and measurements

- Wind turbine technology (historical development, different wind turbine designs and components)

- Aerodynamics (fundamental principles and simple computational models)

- Materials; Structural mechanics (blade mass and structure, loads acting on the blade, stress-strain analysis)

- Wind turbine blade optimization

- Mechanical drive train and nacelle; Electrical system (power transmission, integration of the very variable power production with the electrical grid, rotor speed control)

- Blade manufacturing

- Additional topics: Support structure design, Vibration problems, Offshore wind energy engineering, Wind turbine aeroelasticity, Blade testing, Wind turbine economics

practical teaching
- Introduction to variable wind speed profiles modeling; Measuring equipment

- CAD of basic wind turbine components (including various types of wind turbines)

- Blade design (computation of fluid flow around the blade)

- Thrust and power calculations of wind turbines (by writing and using numerical codes)

- Overview and definition of blade structure and materials

- Wind turbine blade stress-strain analysis

- Wind turbine blade optimization

- Manufacturing blade model or segment and/or blade mould

- Blade testing (static and/or dynamic)

prerequisite

There are no mandatory conditions/prerequisites for course attendance.

learning resources

Classroom, projector, computer (laptop), computational software tools, CNC mill, 3D printer, measuring equipment.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 35
auditory exercises: 10
laboratory exercises: 12
calculation tasks: 5
seminar works: 8
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 15
laboratory exercises: 15
calculation tasks: 15
seminar works: 15
project design: 0
final exam: 35
requirements to take the exam (number of points): 30

references

Hau E, Wind Turbines - Fundamentals, Technologies, Application, Economics, 2nd ed., Springer-Verlag, Berlin Heidelberg, 2006.
Manwell J.F., McGowan J.G., Rogers A.L., Wind Energy Explained - Theory, Design and Application, John Wiley & Sons, Chichester, 2

AGRICULTURAL ENGINEERING

Basics of the phenomenon of transmission and drying techniques

ID: MSc-1365
responsible/holder professor: Zlatanović J. Ivan
teaching professor/s: Zlatanović J. Ivan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: agricultural engineering

goals
Mastering theoretical and practical knowledge in the field of heat and matter transfer in drying processes of wet materials (colloidal, capillary porous and colloidal capillary porous) and introduction to drying process techniques (convective drying), which includes the development of creative abilities and mastery of specific practical skills tasks.

learning outcomes
Upon successful completion of this course, students should be able to:

• Describe and distinguish different drying methods,
• Organize and lead scientific or research projects,
• Prepare and present papers at seminars,
• Determine, formulate, analyze and solve thermodynamic drying problems of agricultural materials,
• Perform thermodynamic calculations for drying of agricultural materials,
• Evaluate the optimal way of drying according to the type of agricultural material, conditions and requirements for drying and storage.

theoretical teaching
1.0. Basic laws of transfer in wet materials: Heat transfer in wet materials; Moisture transfer in wet materials. 2.0. Heat and moisture transfer in wet materials: Thermodiffusion of moisture in gases and solutions; Thermodiffusion of moisture in colloidal bodies; Thermal moisture conductivity in capillary porous bodies; Thermal moisture conductivity in colloidal capillary porous bodies; Basic laws of heat and matter transfer. 3.0. Basic methods of thermal drying. 4.0. Design and calculation of drying plant: Material balance of the dryer; Heat balance dryer; 4.3. Determination of drying agent flow. 5.0. Calculation of belt dryers. 6.0. Calculation of shaft dryers: Dimensioning of basic dryer assemblies; Fan selection; Determination of fuel flow and thermal efficiency; dryers; Determining the basic dimensions of the furnace. 7.0.Calculation of the drum dryer. 8.0. Calculation of fluidized bed dryers. 9.0. Calculation of pneumatic dryers: Calculation of pneumatic pipe dryers; Whirlpool dryer calculation. 10.0. Calculation of dryers with material spraying, spray dryers. 11.0. Calculation of combined dryers: Calculation of combined cyclone dryers; Calculation of combined air fountain dryers. 12. 0. Calculation of chamber dryers. 13.0. Calculation of tunnel dryers.

practical teaching
Practical classes: preparation of seminar papers from the above theoretical units in order to get acquainted with the existing solutions and techniques of drying and monitoring developments in the field; calculation tasks: thermal calculations of different drying methods and types of dryers are made from the aspect of drying methods (convective drying) and condition, shape and dimensions of materials; introduction to the systems of characteristic differential equations, their derivation and basic criteria of similarity of heat and matter transfer.

prerequisite
Defined by the study program / module curriculum.

learning resources

1. Topić M. Radivoj, Osnove proračuna, projektovanja i konstruisanja sušara,Naučna knjiga,Beograd, 1989. 2. Topić M. Radivoj,Bognert Martin, Tehnika sušenja, Zavod za izdavanje udžbenika i nastavna sredstva Beograd,2002., KPN,3. Topić M. Radivoj, Osnove pojava prenošenja i tehnike sušenja (štampani materijali za predavanje Handouts). Primeri urađenih računskih zadataka. Razne tablice i praktikum.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 5

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 50

references

Topić, R.: Osnove pojave prenošenja i tehnike sušenja, Mašinski fakultet u Beogradu, 2013.

Филоненко К. Г., Гришин А. М., Гольденберг М. Я., (1971) Сушка пищевых растительных материалов, "Пищевая промышленность" , Москва.

Лыков В. А., (1950), Теория сушки," Государственное энергетическое издательство", Москва - Ленинград.
Arun S. Mujumdar: Handbook of industrial drying, 3rd. ed., CRC Press, 2006.
Xiao Dong Chen, Arun S. Mujumdar: Drying Technologies in Food Processing, Blackwell publishing, 2008.

Design of agricultur machines and equipment

ID: MSc-1243
responsible/holder professor: Simonović D. Vojislav
teaching professor/s: Simonović D. Vojislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: agricultural engineering

goals
1. Achieving competence and academic knowledge relating to agricultural machinery and equipment. 2. Mastery of specific and practical skills for carrying out of agricultural machines and equipment. 3. Findings to a multidisciplinary approach to achieve optimal results in the design of agricultural machines and equipment.

learning outcomes
After successful completion of this course, studenty should be able to:

- Define the project management plan,
- Define the forces and moments that are plaguing the machines,
- Calculation of pressure and dynamic load of agricultural machinery and equipment,
- master the methods and processes of agricultural machines and equipment,
- Estimates of the outcomes of the project in relation to the initial request,
- Be efficient in teamwork.

theoretical teaching
1. Technical and economic requirements in the design of agricultural machines and equipment.
2. The theory of cutting tillage.
3. The forces acting on the plugging of the body. The stability of the plow.
4. The main parameters of working elements and machines for additional processing of land. Design of machinery with an active working elements. Disc machines with working elements. Conceptions of cultivators, harrows and rollers. The main parameters and design machines to perform several tasks in one pass.
5. Characteristics and design of machinery for fertilizing, seeding and planting.
6. Machines for chemical pesticides and irrigation equipment.
7. Designing machines to harvest the yields.

practical teaching
1. Auditory exercise: a review of contemporary solutions of agricultural machinery for soil preparation. Displaying solutions machine fertilizing, seeding, planting, plant protection and irrigation. Displaying solutions for machine sorting of agricultural crops: forage, grains, yields of root and tubers, vegetables and fruits.
2. Development of the project: The project in the field of agricultural machinery and equipment. Determination of basic parameters. Budget, schedule and technical documentation.
3. Development of arithmetic problems: The task of designing working surface plow body. The task in the field of cutting device. The task in the field of combine harvester.
4. Laboratory Exercise: Profiling working surface plow body.

prerequisite
Passed exams in 7 semesters (defined curriculum study program/ module) and passed items 1.1.5, 1.2.5 of the module IBS

learning resources

1.Veljić M.: Technological processes of mechanized agriculture, MF, Belgrade, 1997.

2. Laboratory installation for profiling working surface plow body, instructions.

3. Veljić M., Written lectures, Belgrade, 2008.

4. Veljić, M.: Instructions for making assignments for the design of the working surface plow body.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 4
calculation tasks: 4
seminar works: 0
project design: 10
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 10
laboratory exercises: 10
calculation tasks: 10
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 0

references

Gligoric R., Mechanisms of agricultural machinery with the settlement tasks, PF, Novi Sad, 2005.
Veljić M., Viewing construction of agricultural machinery, MF, Belgrade, 1992.
Urosevic M., Machinery and apparatus for the application of pesticides, PF, Belgrade, 2001.
Martinov M., Markovic D., Machinery and tools for soil cultivation, the first part, FTN, Novi Sad, 2002.

Design of plants and process and energy systems

ID: MSc-1367
responsible/holder professor: Zlatanović J. Ivan
teaching professor/s: Zlatanović J. Ivan, Zlatanović J. Ivan, Zlatanović J. Ivan, Zlatanović J. Ivan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: agricultural engineering

goals

Mastering the knowledge necessary for the calculation and design of plants and process and energy systems and their use. This includes the development of creative abilities and the mastery of specific practical skills for performing work tasks in engineering practice.

learning outcomes

Upon successful completion of this course, students should be able to:

• Define the basic principles of design,
• Describe the design facility,
• Perform thermodynamic calculations with a choice of computational parameters of outdoor and indoor air,
• Design process systems for livestock and poultry facilities, drying plants and systems in the food industry,
• Organize storage space.

theoretical teaching

1.0.Introductory remarks. 2.0. Historical development of buildings with protected space: Overview of characteristic solutions; Basic ways of providing microclimate; Basic microclimate systems; Defining working conditions of facilities with protected space and calculation; Thermotechnical calculation and definition of mathematical model; Defining and creating programs for optimizing objects with protected space. 3.0. Design of drying devices and plants: Calculation of pneumatic - drum and drum dryers; Determination of design parameters of pneumatic - drum dryers; Structural dimensions of multi-pass drums; Methods for determining the drying regime. 4.0. Theory of wind turbines, wind energy utilization coefficient: Aerodynamic characteristics of wind turbines; Systems for regulating the speed of rotation of the wheel and the power of the wind motor and the automatic orientation of the wheel when changing the direction of the wind speed; Selection of solutions and calculation of wind motor power; Basic parts of wind farms. 5.0. Design of power plants for biogas use: Principle of digester construction; Substrate heating; Sizing of tubular heaters; Digestor vessel insulation. 6.0. Design of energy plants for the use of biomass: Basic principles of energy valorization; Briquetting; Pelleting; Cogeneration and trigeneration; Concept of solution for high temperature sawdust drying plant. 7.0. Heat pump: Ground connection.

practical teaching

Practical classes: Seminar paper is given from some of the above theoretical units in order to acquaint students with existing solutions, their characteristics and monitoring achievements in the field covered by the course program. Laboratory exercise: Determining the hovering speed of different materials (depending on the type, shape, dimensions, humidity, etc.). Calculations are made in order to define and dimension the characteristic solutions from some of the theoretical units. A project is being prepared with a study depending on the selected theoretical unit, which is a continuation of the calculation tasks. Projects include the choice of plant concept and process and energy systems, the calculation and dimensioning of components and the corresponding drawings.

prerequisite
Defined by the study program/module curriculum.

learning resources
1. Topić M. Radivoj, Osnove projektovanja, proračuna i konstruisanja sušara,Naučna knjiga, Beograd, 1989.,KPN; 2. Topić M. Radivoj, Projektovanje i konstruisanje poljoprivrednih postrojenja (teorijski izvodi i laboratorijske vežbe), Mašinski fakultet, 1996.,PRA; 3. Topić M. Radivoj, Martin Bogner, Tehnika sušenja, Zavod za izdavanje i nastavna sredstva Beograd,2002., KPN 4. Radivoje M. Topić, Projektovanje postrojenja i procesnih i energetskih sistema, 2009. (štampani materijali za predavanje Handouts). Primer urađenih projekata i seminarskih radova. Razna uputstva i standardi.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 5

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 50

references
Топић, Р.: Пројектовање постројења и процесних и енергетских система, Машински факултет у Београду, 2013.
Roberts T.C.: Food plant engineering systems, CRC Press, 2002.
Stavros Yanniotis: Solving problems in food engineering, Springer, 2008.
Arun S. Mujumdar: Handbook of industrial drying, 3rd. ed., CRC Press, 2006.
Philip Richardson: Thermal technologies in food processing, CRC Press, 2001.

Geoinformation and remote control of biotechnic systems

ID: MSc-1244
responsible/holder professor: Simonović D. Vojislav
teaching professor/s: Simonović D. Vojislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: agricultural engineering

goals
1. Master the theoretical foundations of measurement and automation of agricultural machines and equipment;
2. Principles of measurement, sensors and methods of measurement non-electrical quantities on agricultural machines and equipment;
3. Automation of tractors and machines;
4. Automation combines: automatic control, regulation of technological devices, measurement and regulation of losses, monitoring,
5. Management in precision agriculture and food processing industry.
6. Monitoring of dinamic machines and proceses in real time

learning outcomes
After successful completion of this course, studenty should be able to:

• Identify the different components of the automation system biotechnical,

• Define procedures for precision farming,

• Interpret hydraulic and pneumatic scheme of agricultural machinery,

• Projected guidance direction of agricultural machinery,

• Organize a complete cycle of precision farming,

• Communicate effectively in a multidisciplinary team.

theoretical teaching
1. Introductory discussion of theoretical bases and methods of measurement and automation of agricultural machines and equipment: navigation leveling measurements, measuring distance (distance, measuring the number of revolutions and torque measuring yield loss measurement, the measurement of quantity and measurement of other parameters; 2 Principles of measurement, sensors , division, operating principles, static and dynamic characteristics, a method of measuring non-electrical quantities on agricultural machines and equipment, can bus system; third Automation tractors and machinery: automatic control of loading, automatic control of connection devices and machines on the tractor, the tractor can bus , automatic control and information systems; 4 combines automation: automatic control of the direction, regulation of the position Header, perform separation and other technological devices (automatic leveling), measurement and regulation of losses, monitoring of combine harvesters; fifth management in precision agriculture GPS and DGPS and automation systems and production lines in food processing industry.

practical teaching
Laboratory exercises:

1. Measurements of the kinematic characteristics of agricultural machinery and equipment;

2. Measurement of energy parameters of agricultural machinery and equipment.

Seminar work at the choice of candidates in the field:

1. Automation of tractors and attachments of agricultural machinery and equipment;

2. Automation of universal self-propelled grain harvesters;

3. Automation of self-propelled combine harvesters for vegetables and industrial crops;

4. Automation of equipment and technological lines for food processing;

5. Application of GPS and DGPS in Precision Farming.

prerequisite
Attended courses of previous years of study and all the conditions defined curriculum of study program / module

learning resources
1. Markovic D.: Automation in agriculture, written lectures and lectures in electronic form, Belgrade, 2007.

2. Markovic D.: Transport in Agriculture, Belgrade, 1997.

3. Automation and measurement of agricultural machinery-handouts.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 10
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 20
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references

Martinov M., My tractor, Res trade, Novi Sad, 2007.
Zivanovic Z., N Janićijević., Automatic transmission vehicles, Belgrade, 2000.
Ribar Z., Control systems, MF in Belgrade, Belgrade 2008.
Bolton W., Instrumentation control systems, EUSEVIER SCIENCE & TEHNOLOGY BOOKS, 2004.
Popovic M., Sensors and measurements, Department of textbooks and teaching aids, Srpsko Sarajevo, 2004.

Managing food safety and quality

ID: MSc-0596
responsible/holder professor: Marković D. Dragan
teaching professor/s: Marković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: agricultural engineering

goals
1.The subject should enable students to acquire knowledge about the concept of certification and its importance for the market, environmental protection and good agricultural practice, the function of certification.

2.Introduction to basic procedures for certification, certification course, participants, their rights and obligations, the general principles of all standards relating to food and industrial processing of food products and exposure with institutions and organizations dealing with food safety in Serbia and abroad.

3.The subject should enable students to acquire knowledge / understanding of contemporary approaches and principles of quality management, quality management functions of the organization, specific methods of management and quality control, new business strategies, new systems and specific quality management activities.

4.Learning about new trends in food production.

learning outcomes
After successfully completing of this course, students should be able to:

1. Define the basic concepts related to standardization and regulations in the production and processing of food

2. Formulate and improve the application of modern quality management system

3. Analyzing the role of certification and its role in the food market, environmental protection and good agricultural practices

4. Preparations risk analysis

5. Applying appropriate standards.

theoretical teaching
Introductory considerations. Prerequisites food safety management. The concept of standardization. The principles and benefits of standardization. regulations and standards applied in agriculture and food industry. The quality management system in food production. The quality of food products. Overview of institutions and organizations dealing with food safety in Serbia and abroad. New trends in food production. Environmental protection.

practical teaching
Practical teaching coupled with interactive lessons take place in the field of modern quality management system operations, the food industry and safety management and quality of products (food). The way the accreditation of laboratories and the introduction of standards in the control of production flows. Planned are two tests and essay.

prerequisite
Attended courses of previous years of study and all the conditions defined curriculum of study program / module

learning resources

1. Markovic D.: Written lectures, Belgrade, 2007.

2. Djekic, I., (2009) Environmental management in food production. University of Belgrade, Faculty of Agriculture

3. D. R. Heldman.; D. B. Lund.: Handbook of food engineering; Taylor & Franncis Group; New York, 2007.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references

Grujic, R., Radovanovic, R. (2007): Quality management and safety in food production. University of Banja Luka, Faculty of Technology (RS / BiH)
Radovanovic, R., Rajkovic, A. (2009): Managing security in the process of food production. University textbook. University of Belgrade - Faculty of Agriculture
Carol Wallace, William Sperber, Sara E. Mortimore: Food Safety for the 21st Century, ,UK, 2011.
Djekic, I., (2009) Environmental management in food production. University of Belgrade, Faculty of Agriculture
Grujic, R. et al. : Quality and Food Analysis, Faculty of Technology in Banja Luka, RS / BiH. 2001

Processing technology of agricultural products

ID: MSc-0600
responsible/holder professor: Marković D. Dragan
teaching professor/s: Marković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: agricultural engineering

goals
1. Student should master the basics of the process of agricultural products(fruits, vegetables, animal products and grains)..
2. Understanding the limitations and specific lines of production and food processing.
3. Introduction to the preparatory process technologies of processing agricultural products (cleaning, washing, sizing and sorting round).
4. Mastering how to process modeling and optimization processes of food preservation using high and low temperatures.
5. Acquiring knowledge about the procedures and equipment for sterilization and pasteurization of food products.
6. Acquiring knowledge about the procedures and devices for cooling and freezing of fruits and vegetables.
7. Understanding the technology of cooling fruits and vegetables.
8. Understanding the technological procedures for freezing and storing fruit and vegetables.
9. Introduction to methods and devices for thawing food product.

learning outcomes
After successfully completing of this course, students should be able to:

1. Define the technological operations of processing of agricultural products

2. Describe and analyze traditional and new technologies of animal products

3. Describe and analyze traditional and new technologies of fruit, vegetables and cereals

4. To model and optimize processes and equipment for sorting and preserving products

5. Manages the technological processes and equipment in industrial plants for the production and processing of food.

6. Applying the appropriate standards.

theoretical teaching
Introductory considerations.Fundamentals of animal products processing technology. Basis of the preparatory process of fruits, vegetables and grains. Washing, cleaning and calibration of fresh fruits and vegetables. Color sorting of fresh and frozen products. Fundamentals of preservation of fruits, vegetables and ready-made food products using high and low temperatures. Heat treatment of fresh products (blanching). Heat treatment of the finished food product (pasteurization and sterilization). Cooling technology and storage of animal products. The technology of cooling and storage of fruits and vegetables. Preservation by freezing. Technology freezing of agricultural products. Effects of freezing rate on quality of frozen products. The changes that occur during freezing of products. Concept and models of refrigerator thermal insulation, cooling fluids, methods for achieving low temperatures, storage, maintenance of the given regime, transport of chilled and frozen fruits and vegetables. Thawing.

practical teaching
Seminar papers

1.Analysis of technologies for producing and processing fruit,

2.Analysis of technology for production and processing of vegetables,

3.Analysis of technologies for production and processing of grains and seeds,

4.Analysis of technology, machinery and equipment for production and processing of meat and dairy products.

prerequisite
Attended courses of previous years of study and all the conditions defined curriculum of study program / module

learning resources
1. Markovic D.: Written lectures, Belgrade, 2007.

2. M. Karel., D. B. Lund.: Physical principles of food preservation; Marcel Dekker Inc; New York, 2003.

3. D. R. Heldman.; D. B. Lund.: Handbook of food engineering; Taylor & Franncis Group; New York, 2007.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references

Miodrag A. Jankovic. "Cooling Technology", published by University of Belgrade, Faculty of Agriculture 2002.
Branislav P. Zlatković.: "The technology of processing and preserving of fruits", published by University of Belgrade, Faculty of Agriculture 2002.
Sava Vujic. "Refrigeration", published by Faculty of Mechanical Engineering, University of Belgrade, 1996.
M. Veres.: Basics of food preservation, Belgrade, 2004.
Thompson, A. K., Fruit and Vegetables: Harvesting, Handling and Storage, Blackwell Pub, 2003.

Skill Praxis M - IBS

ID: MSc-1245
responsible/holder professor: Simonović D. Vojislav
teaching professor/s: Simonović D. Vojislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: agricultural engineering

goals
Practical experience and stay in the student environment in which the student will realize his professional career.

Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineering in such a business system.

learning outcomes
Students get practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, in the context of his future professional competence. Establish the personal contacts and poznastva that will be able to use at school or entering into future employment.

theoretical teaching
Selected topics through practical activities.

practical teaching
Practical work in organizations that perform various activities in connection with mechanical engineering. Selection of thematic areas and commercial or research organizations carried out in consultation with the concerned teacher. Generally a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations engaged in mechanical equipment maintenance, and public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice may also be made abroad. During practice, students must keep a diary in which to enter a description of the tasks performed, the conclusions and observations. Following the practice must make a report to defend the subject teacher. The report is submitted in the form of the paper.

prerequisite
Students of modul IBS

learning resources
Laboratory and IT equipment

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 90
> auditory exercises: 0
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 0

project design: 10
consultations: 10
discussion and workshop: 10
research: 60

knowledge checks: 0
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 70
requirements to take the exam (number of points): 30

references
Markovic D.: Transport in Agriculture, Belgrade, 1997.
prospects
projects

Special techniques and technologies of the drying process

ID: MSc-1366
responsible/holder professor: Zlatanović J. Ivan
teaching professor/s: Zlatanović J. Ivan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: agricultural engineering

goals
Gaining basic knowledge in the field of special techniques and technologies of the drying process (drying by radiation, osmosis, ultrasound, conduction, sublimation, high and super high-frequency current, etc.), which includes the development of creative abilities and mastering specific practical skills to perform work tasks.

learning outcomes
Upon successful completion of this course, students should be able to: • Describe the transfer of heat and matter in drying processes, • List and identify basic drying methods, • Calculate drying processes and design solutions, • Determine drying time, • Evaluate optimal drying method according to the type of agricultural material, conditions, and requirements for drying and storage.

theoretical teaching
1.0. Methods of moisture separation and classification of thermal drying methods according to energy characteristics. 2.0. Thermoradiation drying: Thermoradiation dryers with electric and gas heating; Thermoradiation dryers with electric heating; Thermoradiation dryers with gas as a heat source; Thermal calculation method of thermoradiation dryers. 3.0. Contact drying of materials: Contact drying of materials by heating surface; Contact drying dryers; Drying of materials in liquid media; Contact drying with sudden pressure change. 4.0. Molecular drying (sublimation drying of materials): Mechanism and scheme of sublimation drying of materials; Heat calculation of basic sublimation dryers; Vacuum dryer. 5.0. High and super high-frequency electric field drying: Electricity consumption and the influence of humidity and electric field frequency on the intensity of high-frequency electric drying; High-frequency electric drying generators and high-frequency dryer schemes; Combined methods of drying materials. 6.0. Drying in an acoustic (ultrasonic) field. 7.0. Drying by osmosis. 8.0. Characteristic solutions of dryers from the aspect of construction and energy sources: Solar mobile dryers; Combined solar dryers; Solar systems, drying centers; Farm (park) solar dryers. 9.0. Testing of the module of mobile, universal, ecological, chamber solar dryer for drying biological materials: Mobile, universal, ecological, chamber solar dryer for drying biological materials; Description of measuring installation; Experimental procedure and display of measurement results. 10.0. Drying of fruits and vegetables using solar energy: Drying of fruits using solar energy; Drying vegetables using solar energy; Packing and storage of dried fruits and vegetables.

practical teaching
Practical classes: Preparation of calculation tasks and seminar papers from the above theoretical units in order to dimension the characteristic solutions from some of the studied areas. Laboratory exercise: Study of the drying process of materials in thermoradiation dryers. The aim of the exercise is to study the character of the drying process and obtain the drying curve and the drying speed curve. The seminar paper is given from some of the above theoretical units in order to acquaint students with existing solutions and their characteristics and monitor achievements in the field.

prerequisite
Defined by the study program/module curriculum.

learning resources

1.Topić M. Radivoj, Osnove proračuna, projektovanja i konstruisanja sušara, Naučna knjiga,Beograd 1989.,KPN; 2. Topić M. Radivoj, Projektovanje i konstruisanje poljoprivrednih postrojenja(teorijski izvodi i laboratorijske vežbe), Mašinski fakultet, 1996.3. Primeri urađenih računskih zadataka, PRA;4. Topić M. Radivoj,Bogner Martin, Tehnika sušenja, Zavod za izdavanje i nastavna sredstva Beograd, 2002.,KPN. 5. Topić M. Radivoj, Specijalne tehnike i tehnologije procesa sušenja (štampani materijali za predavanje, Handouts). Primer urađenih projekata i seminarskih radova. Razna uputstva i standardi.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 5

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 50

references

Topić, R.: Specijalne tehnike i tehnologije procesa sušenja, Mašinski fakultet u Beogradu, 2013.

Филоненко К. Г., Гришин А. М., Гольденберг М. Я., (1971) Сушка пищевых растительных материалов, "Пищевая промышленность" , Москва.
Лыков В. А., (1950), Теория сушки," Государственное энергетическое издательство", Москва - Ленинград.
Arun S. Mujumdar: Handbook of industrial drying, 3rd. ed., CRC Press, 2006.
Xiao Dong Chen, Arun S. Mujumdar: Drying Technologies in Food Processing, Blackwell publishing, 2008.

Tractors and self-propelled agricultural machines

ID: MSc-0298
responsible/holder professor: Marković D. Dragan
teaching professor/s: Marković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: agricultural engineering

goals
1. Master the theoretical foundations of power machines-tractors and self-propelled agricultural machine-harvesters; 2. Conception and construction of farm tractors, small tractors and self-propelled chassis; 3. Transmission systems and for connecting the working machinery and mechanisms; 4. Concept of simultaneous transmission of power through the drive wheels and auxiliary shafts, energy balance, 5. The theory of operation, concept and design combines, budgets drive the moving parts and technological devices combine.

learning outcomes
After successful completion of the new course, studenty should be able to:

• Manage the procurement of tractors of appropriate to the characteristics of the available agricultural mechanization tractor by aggregating,

• Organize and water exploitation and maintenance of tractors and self-propelled agricultural machines,

• Perform and implement solutions different conceptions of tractors and self-propelled chassis,

• Make a plan of testing of tractors,

• Identify, formulate and control the ergonomic requirements of the operator.

theoretical teaching
1. Introduction, theory of operation, concept and construction of power machines-farm tractors, mowers and self propelled chassis; 2. Concepts of transmission and energy balance of simultaneous transmission of power through the drive wheels and auxiliary shaft; 3. Concepts, devices and systems for power and aggregate formation tractor-working agricultural machines; 4. Construction and theory of universal self-propelled combine harvesters, 5. Calculations of technological devices combine; 6. Concept drives the moving parts, hydrostatic power transmission components selection and calculation of hydrostatic drive moving parts and technological devices combine.

practical teaching
Laboratory exercises:

1. Practical introduction to technical solutions assemblies tractors, small tractors and self-propelled chassis;

2. Practical introduction to technical solutions and components and technological devices combine.

Computational tasks:

1. Development of arithmetic problems using computers and modern software packages in the field of tractors;

2. Development of arithmetic problems using computers and modern software packages in the field of universal self-propelled combine.

Development of the project:

1. Conceptual design of the tractor and operating self-propelled chassis;

2. Preliminary design in the field of universal self-propelled combine.

prerequisite
Attended courses of previous years of study and all the conditions defined curriculum of study program / module

learning resources
1.Novaković Vl.: Agricultural machinery 1, Belgrade;
2.Marković D.: Agricultural tractors, written lectures, Belgrade, 2006.;
3.Standardi and regulations for universal self-propelled tractors and combine harvesters.
4.Tractors and self-propelled agricultural machine-handouts.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 20
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 10
calculation tasks: 10
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 50

references
Martinov M., My tractor, Res trade, Novi Sad, 2007.
Zivanovic Z., N Janićijević., Automatic transmission vehicles, Belgrade, 2000.
Martinov M., Markovic D.: Machinery and tools for soil cultivation, the first part, FTN, 2002.;
Gligoric R., Mechanisms of agricultural machinery-with the settlement tasks, PF, Novi Sad, 2005.
Veselinov B., M Martinov., Bojic S., Machinery for biosystems, practical, FTN Novi Sad, 2009.

BIOMEDICAL ENGINEERING

Clinical Engineering

ID: MSc-1283
responsible/holder professor: Matija R. Lidija
teaching professor/s: Matija R. Lidija
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: biomedical engineering

goals
To enable practical implementation, in real life clinical conditions, of theoretical knowledge and R&D results in the field of biomedical technology. To provide students with adequate medical knowledge to work in clinical environment. Enabling future clinical engineers to be a part of medical team and participate in every phase of clinical activities, such as: device initialization, adequate device application, device functions in vivo testing, monitoring of medical device or system performance, protection of patients and medical stuff from potential hazards in application of certain technologies, etc.

Introduction to design and maintenance of medical equipment (chirurgical tables, beds, chairs, etc.).

Give a history of medical devices and technologies development with respect to related branches of medicine. Getting to know medical reasons behind the development of certain devices. Overview of medical device classification based on the role they play in the hospitalization process. General introduction to medical device maintenance. Introduction to legislation regarding medical device design and maintenance. Basics of medical device design. Introduction to ARM microcontrollers for biomedical application. Making students capable to design medical devices based on STM 32, ARM, microcontrollers.

learning outcomes
Upon successful completion of this course, students will be able to:

•Apply gamma camera, PET and ultrasound in medicine

•Perform surface electrical stimulation of small intensity and aactivation of afferent system - artificial perception (in the laboratory)

•Perform measurements of evoked potentials induced by transcranial magnetic stimulation and measurement of temperature distribution (in the laboratory).

•Prepare all necessary documents for obtaining ethical permission for clinical work

•Prepare all necessary documents for obtaining a license to use a new instrument in the clinic.

•Distinguish and define the basic principles of diagnostic devices (biochemical analyzer - ECG - Rȍ device)

•Develop applications for the STM32 microcontroller for adequately defined applications

theoretical teaching
Good practices regarding work in clinical environment. Ethics, standards and IT. Concept and basic characteristics of medical device. Medical device vs medical equipment. History of medical devices development. Connection between advances in science and development of biomedical apparatus. Medical device classification. Hospitalization and associated medical instrumentation.

Medical imaging – clinical applications (benefits, protection and potential hazards). DICOM standard. Electrical and magnetic stimulation - clinical applications; influence of electrical and magnetic field at a cellular level (benefits, protection and potential hazards). Clinical applications of laser.

Maintenance definition. Legislation regarding medical device and equipment maintenance. Maintenance organization and planning.Overview of different approaches to maintenance. Precautions regarding medical device maintenance. Adequate working environment and prerequisites for medical device maintenance. Maintenance of various devices and equipment.

Process and design stages of a medical device from an idea to a final product . Literature review: patent survey, marketing survey, setting up the requirements of the application, properties of the components of the device studied. Influence of regulatory aspects to medical device R&D chain. Setting up the schedule, work flow and budget for the project.

Introduction to microprocessors, microcontrollers and embedded systems. ARM microcontrollers architecture. Possible applications of microcontrollers in biomedical devices. Acquisition and processing of biomedical signals using microcontrollers and adequate peripherals. Microcontroller programming using C. Program debugging.

practical teaching
Application of gamma camera and PET (at the Clinical Center of Serbia). Ultrasound applications in medicine (at the MMA). Low intensity surface electrical stimulation. Activation of afferent systems - artificial perception (in the laboratory). Measurement of evoked potentials induced by transcranial magnetic stimulation (of Neurology CCS). Measurement of temperature distribution (in the laboratory). Group exercises - projects:

1. Preparation of material for obtaining ethical permission for clinical work and
2. Preparation of material for obtaining a license to use a new clinical equipment/device.

Basics of operation and maintenance of a variety of devices at the Institute for Cardiovascular Diseases "Dedinje":

Diagnostic devices:

- Biochemical analyzer
- ECG
- Rồ aparatus

Medical intervention devices:

- An electro-scalpel
- Anesthesia machine

Devices for patient care:

- Respirator
- Monitor
- Syringe pump

Auxiliary devices, therapeutic devices and medical devices in general.

Application development for the STM32 microcontroller for the usage of triaxial accelerometer for acceleration monitoring of the individual body parts in various movements.

Developing applications for the STM32 microcontroller for the usage of DS1820 temperature sensor for monitoring body temperature of a patient. Development of simple BAN (Body Area Network).

prerequisite
Attending requirements are defined by the curriculum of the study program/module.

learning resources

1. Written course material (handouts).
2. Printed manuals.
3. DAQ hardware.
4. Personal computers with installed data acquisition and processing software: LabView and MATLAB.
5. Four mikroACQ Kit 3 - STM32 ARM kits with adequate peripherals.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 3
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references

Barbara L. ChristeI: Introduction to Biomedical Instrumentation. Cambridge University Press, 2009.
Bronzino, J.D. (Ed.): The Biomedical Engineering Handbook, 2. ed. CRC Press, 2000.
Myer Kutz (Ed.): Biomedical Engineering and Design Handbook, 2. ed. McGraw-Hill, 2009.
I. Hut, B. Jeftic: MATLAB i Microsoft Office za inženjere (autorizovane skripte).
E. White: Making Embedded Systems. O´REILLY MEDIA , 2011.

Early Diagnostics

ID: MSc-1342
responsible/holder professor: Jeftić D. Branislava
teaching professor/s: Jeftić D. Branislava, Matija R. Lidija
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: biomedical engineering

goals
The goal of this course is to introduce students to the molecular mechanisms of cancer development and existing methods for early diagnostics. Through critical approach to existing methods, and mastering the latest noninvasive or minimally invasive methods for early detection of cancer, student is enabled to take part in modern scientific research and development of new diagnostic methods, as well as application and improvement of existing methods in biomedical practice.

learning outcomes
Upon successful completion of this course, students shall be able to:

•Discriminate and define different types of carcinoma

•Perform measurements using Optomagnetic imaging spectroscopy in the early diagnostics of cancer

•Perform analysis of the results

•Modify and create the appropriate software solutions in Matlab to improve the analysis of the results

•Propose and define the appropriate hardware solutions for existing devices for early diagnostics

•To write and present scientific work in accordance with the standards of professional quality

theoretical teaching
Introduction to cancer research: risk factors, structural, energy and informational differences between normal and cancer cell. Genetics and biochemistry of cancer. Cell cycles: chromosomes and chromosome duplication. Spindle apparatus. Regulatory

mechanisms. Cell cycles in healthy and cancer cells. Molecular basics of cancer: tumor markers, mechanism of action. Types and suitable choice of marker for diagnostic procedure. Demonstrating clinical value of a diagnostic test. Sensitivity and specificity. Existing methods, techniques, and tools for diagnostics. Optomagnetic imaging spectroscopy application in early diagnostics of cancer (cervical cancer, colorectal cancer, oral cavity cancer and melanoma). Machine learning in cancer classification.

practical teaching
1. Seminar paper: assigning paper theme in the field of early cancer diagnostic, instructions for acquiring scientific literature, instructions on methodology for scientific research.

3. Laboratory work: opto magnetic spectroscopy in early detection of cervical cancer (smear test). Comparison with PAP test.

prerequisite
Defined by the curriculum of study module Biomedical Engineering.

learning resources
1. Written course material (handouts)
2. Scientific articles (KOBSON)
3. Optomagnetic imaging device - instruments available in the laboratory of Biomedical Engineering department – Nanolab

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 18
laboratory exercises: 5
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references
Papić-Obradović, M., Rana dijagnostika kancera epitelnog tkiva, Don Vas, Beograd 2012
Koruga, Dj., Tomić, A., System and Method for Analysis of Light-matter Interaction Based on Spectral Convolution, US Patent Pub. No.: 2009/0245603, Pub. Date: Oct. 1, 2009
Lindon, J., Tranter, G., Holmes, J., Encyclopedia of Spectroscopy and Spectrometry, Elsevier, 2000
M. A. Hayat (ed.), Methods of Cancer Diagnosis, Therapy and Prognosis, Volume 1-6, Springer, 2009-2011

Introduction to nanotechnology

ID: MSc-1399
responsible/holder professor: Stanković M. Ivana
teaching professor/s: Vasić-Milovanović I. Aleksandra, Matija R. Lidija, Stanković M. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: biomedical engineering

goals
Introduction to basic elements of nanosystems: materials, energy, information, organization and control. Basic types and characteristics of nanomaterials and nanoparticles; fundamental methods, techniques and equipment for characterization. Intermolecular forces анд potentials. Fundamentals of nano-mechanics, nano-fluidics, nano-chemistry,nano electronics. Coding nanomaterials and biomimicry of nanosystems. Self-assembly and self-organization. Principles of nanorobotics design.

learning outcomes
Upon successful completion of this course, students will be able to:

•Establish the difference between physical and biological processes at the nano level, as well as micro and macro system

•Define and calculate the basic characteristics of micro and nano systems

•Establish the difference and define the basic principles of devices used for the characterization of nano-materials

•Define the basic methods for computer simulation and optimization of nano systems

theoretical teaching
Basic elements of nanosystems: material, energy, information, organization amd control. Importance of considering of processes on nano level. Intermolecular interactions, thermodynamical and statistical aspects of nanomaterials. Introduction to techniques for characterization of nanomaterials with spectroscopic analysis of electromagnetic waves. Mode of operation of radiation and scanning mycroscope. STM and AFM. Basic and additional modes of operation and moduls. Self-assembly criteria and examples of molecular systems formed in the process of self-assembly. Inorganic and organic systems, unspecific and non covalent interactions. Molecular recognition, biomimicry. Theoretical (physical and chemical) aspects of bilogical and techical nanosystems. Nanosystem synthesis, molecular construction blocks. Control of nanosystem synthesis and nanorobots.

practical teaching
Introduction to processes on nano level. Comparison of physical and biological systems on nano level. Basic equations and calculations of characteristic interaction intensity. Comparison with micro and macro systems. Fundamental calculations of characteristic properties. Methods for nanosystem simulation. Methods of computer simulations and optimization of nanosystems. Introduction to nanotechnology instrumentation for vizualization of nanosystems. Basics of software and hardware. Basics of control. Introduction to software simulation of molecular nano systems. Calculated models of nonspecific and noncovalent interactions. Practical aspects and examples of application of biological and technical nano systems. Introduction to instrument assembly for nano system synthesis and introduction to nanorobotic assembly.

prerequisite
Prerequisition for attending this course is that student is regulary attending MAS first semester.

learning resources

1) Handouts from lectures, 2) Matija L., Kojic D., Vasic A., Jovanovic T., Bojovic B., and Koruga Dj., Introduction to nanotechnologies, DonVas/NAUKA, Belgrade, Serbia, 2011, 3) Rodgers,B,Nanotechnology: Understanding Small Systems, CRC Press, Boca Ratom 2008. 4)Nanolaboratory with JEOL-STM/AFM instrumentation for nanotechnologies and JEOL instrumentation for nanofilms.

number of hours: 30

active teaching (theoretical): 12
lectures: 10
elaboration and examples (revision): 2

active teaching (practical): 12
auditory exercises: 8
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 35
requirements to take the exam (number of points): 35

references

Mansoori Ali G.: Principles of Nanotechnology, University of Illinois, 2005.
Wiesendanger R.: Scanning Probe Microscopy and Spectroscopy, University of Hamburg, 1994
Bard.A.J., Integrated Chemical Systems: A Chemical Approach to Nanotechnology, John Wiley, New York, 1994
Rogers,B., Nanotechnology: Understanding Small Systems, CRC Press, Boca Ratom, 2008

Nanomedical Engineering

ID: MSc-1400
responsible/holder professor: Stanković M. Ivana
teaching professor/s: Matija R. Lidija, Stanković M. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: biomedical engineering

goals
Student will get knowledge of наносциенце анд nanotechnology applications in medicine together with good practical laboratory work in characterization of biomaterials with nanotechnological methods, techniques and instrumentation. Student will get knowledge of modern diagnostics and therapeutic nanotechnological methods in medicine and will learn how to prepare classical and biological samples and to characterize them with nanotechnological instrumentation.

learning outcomes
Upon successful completion of this course, students will be able to:

•Distinguish principles of operation and the specific conditions of application of the devices in the field of nanotechnology in medicine

•Recognize the advantages of new medical devices in the field of nanotechnology as opposed to solutions in classical medical devices

•Give suggestions of modification of technical solutions in nanotechnologies with a review to their effective application in medicine

•Write and present scientific work in accordance with the standards of professional quality and in quality equal to the works published in professional journals

theoretical teaching
Short history of medicine:From origins of menkind to Asclepius.From Asclepius to Hippocrates.From Hippocrates to healers.From healers to van Leeuwenhoek.From van Leeuwenhoek to DNA discovery.From DNA to quantum medicine.From quantum medicine to nanomedicine;Basics of molecular medicine:Classical medical approach to diseases. Resorption, distribution, metabolism and excretion of drugs.Interactions and undesirable effects of drugs.Molecular basics of diseases.Basics of molecular nanotechnology and its applications in medicine;Basics of nanomedicine:Nanoparticles and nanomaterials in medicine.Quantum dots based on semiconducting nanoparticles. Quantum dots based on nanomaterials (fullerenes).Adding of hydroxyl groups and other molecules to basic nanomaterials. Use of AFM for intermolecular bonding forces measurements in saline; Nanotechnology and nanobiomedicine:Comparison of classical and nanotechnological methods and techniques use in diagnostics and treatment. Advantages and risks of nanoparticles use in medicine; Nanosensors: Nanosensors for electrical, electro-chemical and optical measurements. Nanosensors for food and beverage analysis; Microtubules: Actine filaments. Intermedial fibers. Microtubules. Proteins added to microtubules. Molecular motors. Myosin. Kinesin. Dynein. Cell division. Cytokinesis; Nanotechnology in pharmacy: Possibilities and range of nanopharmacy. Production of nanoparticles. Barriers in organism. Pharmaceutical nanosystems engineering.Intelligent systems for drug releasing; Nanotechnology in implantology: Nanotechnological implants in rehabilitation medicine. Nanoimplants in stomatology. Characterization of stomatological materials by AFM. Nanoimplants in dermatology; Nanotechnology and diabetes: Main sorts of diabetes. Insulin. Complications. Medical nanobots for diabetes control. Methods; Biocompatibility of nanomedical materials: Biocompatibility of coated diamond material. Biocompatibility of fullerenes and carbon nanotubes.Biocompatibility of fluoro-carbon polymers.

practical teaching
Drugs spectroscopy:UV-Vis,IR spectroscopy;Nanotechnological characterization of drugs:STM, AFM and MFM application.Paramagnetism degree assessment of drugs.Paramagnetism/diamagnetism dynamics of drugs at nanotesla level;Biocompatibility of nanomaterials:Analysis and characterization of nanomaterials surface with nanotechnological instrumentation.Toxicological tests of nanomaterials and nanoparticles;Nanoprobe measurements:Dynamic nanophotonic probes.Spectral ballistic probes based on nanoparticles size.Quantum nanoprobes based on encapsulated fullerenes.Adding of soluble groups to encapsulated fullerenes;Implants characterization:Implants characterization by STM, AFM and MFM.Implants characterization in saline by AFM.Sample preparing techniques.Assessment of mechanical,electrical and magnetic characteristics of materials.

prerequisite
Fractal Mechanics, Introduction to Nanotechnology , Signal processing, Nanotechnology

learning resources
Written material for every lecture (Handouts), NanoLab: modern NanoProbe device with STM/AFM/MFM, Opto-magnetic spectroscopy device, Chemical Vapor Deposition for thin (nano) films, UV/VIS spectometer, NIR spectometer,microscope

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 5
calculation tasks: 0
seminar works: 4
project design: 0
consultations: 1
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 7
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

Papić-Obradović,M., Miljković,S., Matija,L., Munćan J., Koruga, Đ.,Osnove Nanomedicine, DonVas/Nauka, Beograd, 2011
Matija, L., Kojić, D., Vasić, A., Bojović, B., Jovanović, T., Koruga, Đ., Uvod u nanotehnologije, DonVas/Nauka, Beograd, 2011
Kumar,S.S.R, at.al. Nanofabrication Towards Biomedical Applications, Wiley-VCHWeinhaimen, 2005.
Malsch,H.N., Biomedical Nanotechnology, CRS Press, Boca Raton, 2005
Freitas,R.A., Nanomedicine, Volume IIA:Biocompatibility, Lands Biscience, Austin, 2003.

Nanotechnology

ID: MSc-1282
responsible/holder professor: Matija R. Lidija
teaching professor/s: Matija R. Lidija, Stanković M. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: biomedical engineering

goals
Goal of this subject is for students to acquire knowledges of: electron tunnelling phenomena, molecular atractve and repulsive forces, nanomaterials, conversion and transport of energy on nanoscale level. Introduction of basic methodes, techniques and devices for characterisation of nanomaterials: Scanning NanoProbe microscopy and spectroscopy. Nano electrochemical cell. Characterisation of conductive, magnetic and non-conductive materials: inorganice as well as biological. Nano films: characterisation and modification of sample surfaces by STM/AFM/MFM methodes.

learning outcomes
Upon successful completion of this course, students will be able to:

•Distinguish between the basic components and principles of electron tunneling as well as the basic components and principles of attraction-repulsion effects
•Apply basic theoretical and experimental knowledge to analyze nano system
•Work on devices for characterization of nanomaterials, STM and AFM
•Carry out appropriate preparation of various samples for the scanning probe microscopy
•Performs characterization of materials at the nano level
•Apply acquired knowledge of software analysis of graphical and analytical data obtained by scanning probe microscopy

theoretical teaching
Conditions for beginning and development of nanotechnology. Basic terms from experimental and theoretical aspects of scanning tunnelling mycroscopy and spectroscopy. Schroedinger equation and electron tunnelling. Technologioes based on electron tunneling effect. Organization of processes of electrochemical interactions. Characterization of materials based on intermolecular forces. Alternative methodes and techniques for spectroscopy and scanning tunnelling microscopy methodes. Introduction to applied nanotechnologies. General areas of application of scanning tunnelling microscope and nanoprobe microscopy. Studying of solid and liquid materials on nanoscale. Solid state physics on the level of nanometers. Application of nanotechnologies in research of organic molecules, drugs and biomacro molecules(nucleic acids, proteins and membrane aggregates). Metrology and standards in nanotechnology. Material modifications on nano level. Integrational aspects of nanotechnology based on physics and chemistry. System aproach to nano-molecular sensores and devices engineering.

practical teaching
Practical lessons: Demonstratory practice from nanotechnology instrumentation. Introduction to abilities and operations of scanning tunnelling microscope. Basic assemblies and principle of tunneling electron conrole. Practical work in sofrware for gathering data from sample analysis. Introduction with atomic force microscope. Comparing posibillities and results of STM and AFM. Basic assemblies and principle of attractional and repulsive forces controle. Nano consoles: characteristics, types, observing them by high magnification CCD camera. Nanomaterial images analysis. Introduction and operation with software tools for acquiring STM and AFM images. Difference between graphical and analytical data. Operation of nano-fluid cell and electrochemical cell.

prerequisite
Enlisted in 2nd semester of Master studies. Recomended: Introduction to nanotechnology.

learning resources
NanoLaboratory with Chemical vapor deposition device for making thin films, NanoProbe microscope with integrated STM/AFM/MFM, electrochemical cell and fluid cell.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 10
calculation tasks: 0
seminar works: 3
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 0
final exam: 35
requirements to take the exam (number of points): 35

references
L. Matija, D.Kojić, A. Vasić, B.Bojović, T.Jovanović, Đ.Koruga,Uvod u nanotehnologije, DonVas, Beograd, 2011
Tošić,B. i sar., Primena diferencijalnog racuna u analizi nanostruktura, VANU,Novi Sad, 2005
Dj.Koruga, S.Hameroff, J.Withers, R. Loutfy, M.Sundareshan., Fullerene C60: History, physics,nanobiology, nanotechnology, North-Holland -Elsevier, Amsterdam, 1993
Hornyak,G.L. et. al, Introduction to nanoscience and nanotechnology, CRC Press, Boca Raton, 2009
Hanson,G.W., Fundamentals of nanoelectronics, Prentice Hall, New Jersey, 2008

Signal Processing

ID: MSc-1343
responsible/holder professor: Jeftić D. Branislava
teaching professor/s: Jeftić D. Branislava
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: biomedical engineering

goals
Introduction to basic concepts and knowledge related to continuous-time and discrete-time signals, biomedical signal analysis in time domain as well as in frequency domain, digital processing of deterministic and stochastic signals, digital filter design. Student is introduced to concepts of digital image, image quality enhancement, frequency domain processing, morphological processing and image compression.

learning outcomes
Upon successful completion of this course, students shall be able to:

•Apply Matlab software in the analysis and processing of the major electrophysiological and kinematic time series and in the analysis of digital medical images

•Form and implement the program for signal acquisition and properly choose acquisition system parameters depending on the type of biomedical signal

•Master the application and the characteristics of Fourier transform (discrete Fourier transform, fast Fourier transform, Z-transform)

•Distinguish characteristics of different biomedical signals (EEG, ECG, EMG, joint angles,muscle forces, medical images ...) in time and frequency domain

•Select and apply different filtering methods depending on the characteristics of the signal being processed and the types of further applications of such signals

•Form a user interface for signal processing and displaying, adequately present time series, image and signal processing results in the time, frequency and time-frequency domain

theoretical teaching
Deterministic and stochastic biomedical signals. Electrophysiological signals - ENG, EMG, ECG, EEG. Discrete signal analysis in frequency domain: Fourier transform, FTDS, DFT, FFT. Z-transform. Sampling theorem. Spectrogram. Correlation. Digital processing of continuous signals: continuous signal discretization, systems for signal discretization and reconstruction (A/D, D/A conversion). IIR filters. FIR filters. Discrete stochastic signals.

Image formation, image quality enhancement, frequency domain processing, morphological processing, image segmentation and different methods of image compression.

practical teaching
Introduction to Matlab for digital signal and image processing. Import of various biomedical signals from PhysioBank data bank. Signal spectral analysis. EMG, ECG and EEG signal processing and analysis. Detection of characteristic signal parameters. Digital filter design. Biological systems modelling. Basics of image processing in Matlab. Image Processing Toolbox. Medical image processing.

prerequisite
Required: Fundamentals of biomedical engineering, Anatomy and physiology of man.

learning resources
Auditory room equipped with computer, video beam, internet connection and accompanied inventory. Computer room with 30 computers with needed software installed. [1] Handouts - lectures. [2] Handouts - Auditory exercises.

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 14
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 3
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Najarian, Kayvan, and Robert Splinter. Biomedical signal and image processing. CRC press, 2012.
John, Semmlow. Circuits, Signals and Systems for Bioengineers. Elsevier Inc. 2018.
Ingle, Vinay K., and John G. Proakis. Digital Signal Processing Using MATLAB: A Problem Solving Companion. Cengage Learning, 2016.
Rangayyan, Rangaraj M. Biomedical signal analysis. Vol. 33. John Wiley & Sons, 2015.
Shiavi, Richard. Introduction to applied statistical signal analysis: Guide to biomedical and electrical engineering applications. Academic Press, 2010.

Skill Praxis M - BMI

ID: MSc-1345
responsible/holder professor: Jeftić D. Branislava
teaching professor/s: Jeftić D. Branislava, Matija R. Lidija
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: biomedical engineering

goals
Introducing students to operation and maintenance principles of instruments, apparatus and devices used in different medical fields, especially in clinics and medical centers. Upgrading theoretical knowledge and developing practical skills through practical experience in the environment where students shall develop their future professional career.

learning outcomes
With mastering the course program, students get familiar with: 1. clinic's organizational processes and problems, especially informational processes, databases 2. functioning and maintenance of instruments for measurements, apparatus, and devices for diagnostics and therapy 3. processes of instrumentation, apparatus, and device maintenance.

theoretical teaching
Introducing students to the practice plan and schedule, procedures, rules, documents related to the protection on work.

practical teaching
Visits to medical institutions, hospitals, and health centers. Getting familiar with work conditions in our country, and establishment of communication system with doctors (adoption of medical terminology). Apparatus and devices management for early diagnostics of cancer and melanoma,ophthalmic procedures for the constitution of sight. Interpretation of obtained results from the aspect of sensitivity and specificity. Analysis of functioning of ECG, EEG, CT, MRI, ultrasound, etc. Recording and analysis of information pathways, making the data base in clinics, introduction to the medical documentation.

prerequisite
Attending praxis in the institution.

learning resources
Biomedical lab 2 at the Faculty of Mechanical Engineering.

number of hours: 90

> **active teaching (theoretical):** 10
> lectures: 10
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 70
> auditory exercises: 0
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 70
> project design: 0
> consultations: 0
> discussion and workshop: 0
> research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 60
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
Practicum for Biomedical Engineering (handout).
Practicum in anatomy and human physiology for engineers (handout).

Spectroscopy methods and techniques

ID: MSc-1398
responsible/holder professor: Stanković M. Ivana
teaching professor/s: Matija R. Lidija, Stanković M. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: biomedical engineering

goals
Introducing students to fundamentals of spectroscopic methods and techniques. Through theoretical lectures and practical work student masters the understanding of light-matter interaction and how this interaction can be used to acquire information about structure of the matter. Through practical work on in the laboratory and analysis of spectral data student learns to apply acquired knowledge about structure of the matter in order to improve and control quality of various products in food industry, pharmacy, and other industrial branches, as well as perform characterization of new materials, biomaterials and biological samples with the purpose of applications in biomedical engineering for early detection of bio-markers, pathological changes and diseases.

learning outcomes
Upon successful completion of this course, students will be able to:

•Use different measurement instruments and methods of UV-Vis / NIR and FTIR spectroscopy

•Work in the laboratory and perform characterization of materials using appropriately selected spectroscopic methods

•Determine composition, as well as the chemical and physical properties of the tested materials Perform multivariate spectral analysis using computer software packages

•Calculate the ratios of components of interest in the samples, based on the spectra of samples

•Carry out the selection of spectral variables of interest for the given problem and define the inputs and outputs for diagnostic system

theoretical teaching
Introduction to Spectroscopic methods and techniques. Classification of spectroscopy methods. Dual nature of light. Electromagnetic radiation. Light – matter interaction. Ultraviolet and visible spectroscopy. UV/VIS spectral interpretation, examples. Infrared spectroscopy: classification, types of spectrometers, accessorizes, sample preparation and acquisition modes. IR spectra interpretation. FTIR spectromicroscopy: transmittance, transflectance, attenuated total reflectance. Quantitative and qualitative analysis of FTIR hyperspectral images.Near infrared spectroscopy. Preprocessing of NIR spectra. Multivariate analysis: principal component analysis, soft independent modeling of class analogies, partial least squares regression, calibration and validation of models. Multivariate analysis applications on real spectral data. Aquaphotomics. Raman spectroscopy. Applications of Raman spectroscopy.

practical teaching
1. Practical work using UV/Vis/NIR spectrometer Lambda 950:

1.1. Preparation of artificial food dyes solutions in water and determination of dye color on the basis of absorption peaks in visible region

1.2. Determination of protection factor of sunglasses on the basis of glass absorption in UV region

2. Practical work using FTIR imaging system Spotlight 400 (Perkin Elmer) using ATR mode:

2.1. Preparation of samples of 2 unknown pharmacological substances and spectral acquisition with the purpose of their identification. Identification of unknown substances using spectral database and concluding whether they belong to the class of doping drugs.

2.2. Preparation of aqueous glucose solutions with varying concentrations; acquisition of spectra and determination of the presence of glucose based on its absorption peaks in fingerprint region. Preparation of sodium chloride aqueous solutions, spectral acquisition and comparison with the spectra of aqueous glucose solutions.

2.3. In vitro spectral acquisition of blood and identification of the compounds visible in infrared region.

3. Practical work using FTIR Spotlight 400 imaging system – imaging mode

Demonstration of microspectroscopic analysis of cervical cytological smears belonging to different PAP groups. Acquisitions of hyperspectral images and identification of healthy and cancer cells based on their spectra.

4. Practical work using UV/Vis/NIR spectrometer Lambda 950:

4.1. Acquisition of spectra of aqueous glucose solutions in the NIR region.

4.2. Demonstration of preprocessing techniques and regression analysis for determination of glucose concentration.

4.3. Construction of aquagram and determining of glucose influence on hydrogen bonds in water.

prerequisite
Defined by the curriculum of the study module Biomedical engineering

learning resources
1. Written course material (handout)

2. Scientific articles (KOBSON) - University network is available on laboratory computers

(Nanolab) and cabinet 300

3. MATLAB, The Unscrambler, Pirouette, SPSS, Origin - sofwares available in full or trial version

4. VIS-NIR, NIR Hamamatsu spectrometers (Hamamatsu, Japan)- -Nanolab

5. FT-IR imaging system-microscope and spectrometer (Perkin Elmer)-Nanolab

6 UV/Vis/NIR spectrometer Lambda 950 (Perkin Elmer, USA) - Nanolab

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 18
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 8
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 25
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references
Crouch, S., & Skoog, D. A. (2007). Principles of instrumental analysis.Thomson Brooks/Cole, Australia
Michael J. K. Thomas, David J. Ando (Eds.). (2008)Ultraviolet and visible spectroscopy: Analytical Chemistry by Open Learning, 2nd Edition, John Wiley & Sons.
Stuart, B. (2005). Infrared spectroscopy. John Wiley & Sons, Inc..
Siesler, H. W., Ozaki, Y., Kawata, S., & Heise, H. M. (Eds.). (2008). Near-infrared spectroscopy: principles, instruments, applications. John Wiley & Sons.
Jue, T., & Masuda, K. (2013). Application of near infrared spectroscopy in biomedicine. Berlin: Springer

CONTROL ENGINEERING

Automatic Control

ID: MSc-0286
responsible/holder professor: Lazić V. Dragan
teaching professor/s: Lazić V. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: control engineering

goals
• to provide theoretical basis, proofs of theorems and more detailed definitions than in the basic course (Introduction of Automatic Control) to get students familiar with the area and therefore fully understand the essence of matter.

• to include all the issues which usually listens worldwide at a course of control

• to enable students to follow the following subjects in this Department

learning outcomes
• The acquisition of wider knowledge of the automatic control, as a technical field that requires a modern engineer

• identify and use the methods needed for analysis and synthesis of controllers in the control systems, and the entire control systems

• the implementation of computers and MATLAB and address the underlying problems of the automatic control, as well as other engineering problems

• the analytical and / or experimental investigation of the basic dynamic and static characteristics of the systems

theoretical teaching
The concept of state space. Linear and nonlinear systems, time invariant and time varying systems. Definition of mathematical models in total coordinates and the coordinates of the absolute deviations. Defining the mathematical model in state space, relationship with differential equation and the transfer matrix of the system. Algorithms for the transition from one form of mathematical model to another. Lyapunov's concept of stability. Different properties of stability of the zero steady state: stability, attraction, asymptotic stability. Different characteristics of system stability: stability, border of stability and unstability. The concept of controllability and observability. Logarithmic frequency response and Bode diagrams. Algebraic stability criteria and frequency stability criteria: Hurwitz, Nyquist, Bode, Cipkin, Mihailov.

practical teaching
Practical training shall include the computational tasks which illustrates the exposed material given by the definitions or by any theorem. Connecting different types of mathematical models of linear systems: differential equations, equations of the state and the output equations, transfer functions and block diagram of the system - the transition from one form to another model. Simulation results for the illustration the above definitions and theorems are done on personal computers using MATLAB. In this subject much more tools, commands, scripts, ... from MATLAB will be used, as compared to those obtained in the subject Introduction of Automatic Control.

prerequisite
Passed course Introduction of Automatic Control and nothing more

learning resources

• Script on website: http://au.mas.bg.ac.rs/Nastava-Kau/Nastava_Download.htm

• Licensed Software in the possession of the Faculties.

• Freeware software.

• PCs.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 18
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Dragan Lazic, "AUTOMATIC CONTROL", Script, Faculty of Mechanical Eng., 2007

Automatic Control

ID: MSc-0566
responsible/holder professor: Ristanović R. Milan
teaching professor/s:
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: control engineering

goals
Acquisition of knowledge from the theory of linear control systems.

learning outcomes
Acquiring the knowledge obtained is used in engineering practice and the basis for monitoring the course of nonlinear systems and advanced courses of synthesis of linear systems.

Student is able to perform analysis and synthesis of PID control in linear systems.

Student is able to perform analysis of linear state space systems using the Matlab Simulink environment.

Student is able to perform analysis of linear systems in frequency domain using the Matlab Simulink environment.

theoretical teaching
P, PI and PID control. Integrator windup. Tuning of PID controller. Analysis of system in state space. Forms of model in state space: controllable canonical form, observable canonical form, digonal canonical form. Tranformation of state space models. Direct solution of the system motion. Concept of controllability. Concept of observability. Stabilization of system in state space. Influence of state feedback on controllability and observability. Phase portrait. Lyapunov concept of stability. Characteristics of system stability. General frequency stability criteria: Nyquist and Bode criteria. Tsipkin formulation of Nyquist criterion. Introduction to system robustness.

practical teaching
The analysis using software tools MATLAB and Simulink. Experimental determination of the system transfer function. Experimental setup of the regulator.

prerequisite
Basic automatic control knowledge.

learning resources
• Literature on the website "Automatic control"

• Licensed Software in the possession of the Faculty.

• Freeware software.

• PCs.

• Laboratory of automatic control

• Rotary inverted pendulum

• Aero pendulum.

• NI cRIO.

number of hours: 75

active teaching (theoretical): 45
lectures: 30
elaboration and examples (revision): 15

active teaching (practical): 15
auditory exercises: 5
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 5
calculation tasks: 15
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references

Karl Johan Aström, Richard M. Murray, Feedback Systems, PRINCETON UNIVERSITY PRESS, New Jersey, 2008
Aström K., H• agglund, T., PID Controllers: Theory, Design, and Tuning, Instrument Society of America, Research Triangle Park, NC, 1995.
Nise N.S. Control Systems Engineering, John Wiley & Sons (Asia), 2011.
Dorf R.C., Bishop R.H., Modern Control Systems, Prentice Hall, NJ, 2008.
Franklin G.F., Powell J.D., Emami-Naeini A. Feedback Control of Dynamic Systems, Prentice Hall, NJ, 2009.

Bioaumatics

ID: MSc-0676
responsible/holder professor: Ribar N. Srđan
teaching professor/s: Ribar N. Srđan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: control engineering

goals
Introduction to the principles of work of biological systems from the point wiev of automatic control. Spotting and analyses the specificity and complexity of these systems, as control systems.

learning outcomes
Biological systems are the most advanced automation systems. With the emergence of new breakthroughs in technology, such as robotics, artificial intelligence, biotechnology and others it became necessary to study these systems created by nature for the purposes of techique. In the context of the development of techniques more and more demands are posted to expand the traditional frames of automatic control and the study of automatic control system with intelligence.

theoretical teaching
The term bioautomatics. Similarities and differences of automated processes in biological and technical systems. The importance of research bioautomatics for the apply in techniques. The basic building blocks of biological systems at the level of molecules, cells, organs and organisms. Energy aspects of biological processes. Basics of bioinformation processes. Basic structure responsible for energy and information processes in biological systems. Control systems in biological organisms. Regulatory functions in biological systems. Biomechanical basics of locomotion process. Memorising and learning at biosystems. Basics of natural and artificial intelligence. Theory bioadaptive control. Biological sensory systems. The relation of the object and control system in bioautomatics. Bioautomatics as a field that studies the systems of automatic control with intelligence.

Basics of biotechnical devices and appliances: biosensors, information machines at the molecular level. Control systems in the technique based on knowledge of biological systems work. Application solutions from biological systems work in robotics, bioreactors, human-machine system and other areas of mechanical engineering, electrical engineering and biomedicine.

practical teaching
Basic mathematical models analysis of bioinformation process. Simulation of different mathematical models of nerve cells (Hodgkin-Huxley model, Fitz Hugh Nagumo model) and examples of their qualitative analysis.

prerequisite
Enrolled master studies

learning resources
1. Written material from the lecture (handouts)

2. Matlab, Mathematics and appropriate software tool

3. Material for exercises in electronic form available on the website

number of hours: 75

> **active teaching (theoretical):** 35
> lectures: 30
> elaboration and examples (revision): 5

active teaching (practical): 28
auditory exercises: 10
laboratory exercises: 2
calculation tasks: 4
seminar works: 1
project design: 10
consultations: 1
discussion and workshop: 0
research: 0

knowledge checks: 12
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references
Written material from the lecture (handouts)
Matlab, Mathematics and appropriate software tool
Material for exercises in electronic form available on the website

Computer Control

ID: MSc-1275
responsible/holder professor: Jovanović Ž. Radiša
teaching professor/s: Jovanović Ž. Radiša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: control engineering

goals

• Introducing of: nature of computer control systems (CCS) related to types of signal transfer; real CCS as mainly presented in the practice; choice of physical model of CCS; mathematical modeling of CCS.

•Mastering of: methods of determining of static and dynamic characteristics of CCS; real time computer control by discrete algorithms.

•Off line use of MATLAB as software standard of automatic control.

learning outcomes

• Exact but not approximate treatment of CCS according to their nature.

• Scientific and engineering treatment of CCS as dominantly represented in practice.

• Applying the methods of analysis and synthesis of controller in CCS, as well of whole CCS.

• Solving problems of calculation nature by means of computer and MATLAB in the "off line" mode, related to the analysis or synthesis of CCS.

• Determining of dynamic and static characteristics of CCS.

theoretical teaching

• Introduction in Computer Control (CC): specific nature of CCS, importance and examples

• Samplers, quantization and coding: real and ideal samplers, mathematical description, technical realization; description of quantization and coding.

• Complex and frequency images of ideal sampler output:determination; Shannon's theorem.

• CCS transfer characteristics: definition in the frequency and s-domain.

• Systems for signal duration extension: definition, analysis and transfer characteristics.

• Z-transform: definition,transfer characteristics in z-domain.

• Block digrams of CCS: algebra of s and z block diagrams.

• Modeling and analysis of CCS: classical mathematical modeling, static characteristics and types of action.

• State concept of CCS: modern mathematical modeling, properties and solving.

• Dynamic properties of CCS: definitions, determining, criteria.

practical teaching

PA:

Examples, determining:

•graphically, of signal in receiver; of physical real CCS

•analytically, x*(t); of quantization and coding

•X*(s) and X*(jω); application of Shannon's theorem

•of discrete transfer characteristics

•transfer characteristics of holds and analysis

•of z-images; of originals

Examples:

•applying of z-block algebra;

•discretization of differential behavior equation; determining of discrete state and output equations; determining of motion and response

•testing of controllability, observability, stability

PL:

Determining in MATLAB:

•Simulation of different types of signal transfer

•X*(s) and X*(jω)

•hold characteristics

•z-images, originals

•discrete mathematical models

•dynamical properties

•sampler output response at oscilloscope

•CC of physical object in real time

PZ:

•Manipulation with mathematical models, determining of static and dynamic characteristics

prerequisite

• Basic knowledge of automatic control.

• Basic computer knowledge based on use of PC.

• Basic knowledge of undergraduate mathematics.

learning resources

1.Manuscript at http://au.mas.bg.ac.rs/Nastava-Kau/Nastava_Download.htm, DVL

2.Ljubomir Grujić: Discrete systems (in Serbian), Mechanical engineering faculty, Belgrade 1991, KDA, library and bookstore of MEFB

3.Power supply, function generator, oscilloscope, lab. for Digital control systems, EOP/LEO

4.Protoboards, integrated circuits, ADDA electronic card, Lab. for Digital control systems, EOP/LEO

5.Object of control, Lab. for Digital control systems, EOP/LPI

6.Licensed and freeware software, MEFB

6.PCs, Lab. for Digital control systems and computer lab. MEFB

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 16
laboratory exercises: 13
calculation tasks: 1
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 10
calculation tasks: 10
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Ljubomir Grujić: Discrete systems (in Serbian), Mechanical engineering faculty, Belgrade 1991, KDA, library and bookstore of MEFB
Benjamin C. Kuo, Digital control systems, Holt Rinehart and Winston, Inc., New York, 1980., KSJ, available in library of MEFB
H. F. Vanlandingham, Introduction to digital control systems, Macmillan Publishing Company, New York, 1985.
C. H. Houpis, G. B. Lamont, Digital control systems, McGraw-Hill, New York, 1992.
C. L. Phillips, H. T. Nagle, A. Chakrabortty, Digital Control System Analysis and Design, Pearson, 2015.

Dynamic systems modelling, identification and simulation

ID: MSc-1379
responsible/holder professor: Ribar N. Srđan
teaching professor/s: Ribar N. Srđan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: control engineering

goals
To acquaint the student with the basic principles and stages of mathematical modeling and identification of dynamic systems. To acquaint the student with the work with the Matlab Simulink simulation package.

learning outcomes
Introduction, acceptance and mastering of basic principles of mathematical modeling in the field of dynamics of material movement, fluid and fluid-thermal processes, dynamics of machines and motors, traffic-transport means and modern plants in energy. Acquiring knowledge for verification of mathematical models of dynamic systems experimentally and identification of parameters of mathematical models using the Simulink package.

theoretical teaching
Mathematical modeling of objects and processes. Dynamics of fluid processes. Dynamics of fluid-thermal processes. Dynamics of heat exchangers. Dynamics of machines and engines. Dynamics of traffic means of transport. Dynamics of aircraft. Vessel dynamics. Dynamics of construction machines. Dynamics of power plants. Dynamics of boiler plants. Dynamics of hydropower plants. Identification of dynamic systems. Simulation of dynamic systems using the Simulink software package. Basic methods for identification of mathematical models of objects using Simulink software package.

practical teaching
modeling of dynamic systems on examples of fluid, fluid-thermal processes: system level dynamics, model of incompressible fluid flow process through long pipeline, compressible fluid flow model through tank, rigid and elastic hydraulic shock model, floor heating model, room temperature field model, model steam boiler. Identification of mathematical models of modeled dynamical systems. Simulation of continuous and discrete automatic control systems. Simulation of hybrid automatic control systems.

prerequisite
Defined by the study program / module curriculum.

learning resources
D. Lj. Debeljkovic, G. V. Simeunovic, V. S. Mulic, Mathematical Models of Objects and Processes in Automatic Control Systems ", Faculty of Mechanical Engineering, Belgrade, Belgrade, 2006,

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 16
> laboratory exercises: 4
> calculation tasks: 0
> seminar works: 6

project design: 4
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 10
final exam: 30
requirements to take the exam (number of points): 35

references

Industrial Automation

ID: MSc-0599
responsible/holder professor: Ristanović R. Milan
teaching professor/s: Ristanović R. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: control engineering

goals
To introduce students to the contemporary industrial control systems, design and technology of their realization, component selection and practical implementation of simple solutions, as well as the role of Industrial Automation in Industry 4.0.

learning outcomes
The acquired knowledge is used in engineering practice. The student is competent to understand modern control systems in the industry, component selection and practical implementation of simple solutions. Student is able to implement simple solutions of electric, pneumatic and electropneumatic control. Student is able to create project with Simatic S7-1200 PLC in programming language STEP 7 according to the standard IEC 61131-3. Student is trained to solve problem of sequential and real time control. Student is able to create HMI project with operators panel.

theoretical teaching
Overview of the development of automation in the industry. Definition of industrial automation. Piramide of industrial automation. Electrical control. Components of electrical contact control (push buttons, proximity switches, contactors and relays, time relays, switches, relays, pulse relays, solid-state relays, residual current device, safety shutdown, bouncing contacts, high voltage electrical discharge). IP protection rating. Displaying electrical contact control. Basic coupling with electric contact control. Control of three-phase induction motors. Pneumatic control. Perform pneumatic installation. Compaction systems and air preparation. Pneumatic cylinders. Pneumatic valves. Electro-pneumatic control. Programmable controllers. Characteristics of programmable controllers. CPU structure. Users program. Input/output modules. Programming the controller according IEC61131-3. Programming languages. Writing programs. Basic functions. Timers. Counters. Sekvential control. Analog value processing. Interrupts. Real time control. Communication between the controllers (Profibus, Profinet, ...). Human-machine interface. Distributed control and SCADA systems. Industrial automation and Industry 4.0

practical teaching
Examples of implemented systems. Practical aspects of election management system components. Realization of simple solution in electrical, pneumatic and electro-pneumatic technology. PLC controllers programming. Development of SCADA system.

prerequisite
Attended courses in automatic control, computer control and digital systems.

learning resources
M. Ristanovic, Industrial Automation, printed lectures
Laboratory for Industrial Automation
Siemens SIMATIC S7-1200
Siemens SIMATIC KTP-600PN
Siemens SIMATIC TP 700
TIA PORTAL - licensed software

number of hours: 75

active teaching (theoretical): 45
lectures: 30
elaboration and examples (revision): 15

active teaching (practical): 20
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 3
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 10
final exam: 30
requirements to take the exam (number of points): 50

references
M.Ristanovic, "Industrial Automation", in Serbian, University of Belgrade - Faculty of Mechanical Engineering, 2020., ISBN 978-86-6060-040-2
Schmiedt, Dietmar et. al, "Steuern und Regeln für Maschnienbau und Mecha- tronik", Verlag Europa-Lehrmittel, Haan-Gruiten, 2010.
Berger, Hans "Automating with STEP 7 in LAD and FBD", Publicis Corporate Publishing, Erlangen, 2005.
Tapken, Herbert "SPS Theorie und Praxis", Verlag Europa-Lehrmittel, Haan-Gruiten, 2011.
Stenerson J., Industrial automation and process control, Prentice Hall, 2003

Industrial process control

ID: MSc-1380
responsible/holder professor: Ristanović R. Milan
teaching professor/s: Ristanović R. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: control engineering

goals
To introduce students to methods of design of control systems and real time control.

learning outcomes
The acquired knowledge is used in engineering practice. The student is competent to understand electrohydraulic and electromechanical servosystems and implementation of simple solutions. The student is able to commission servo drive and frequency controller. The student is able to implement and tune control algorithms in real time.

theoretical teaching
Electrohydraulic actuation systems. Working fluids. Selection of actuation system structure. Electrohydraulic systems control structure selection. Integration of electrohydraulic actuation systems. Basic actuation systems structure. Static and dynamic calculations. Numerical simulations of mathematical models. Electromechanical servosystems. Control of asynchronous and servo motors. Basic control structure's. Networking of servo drives and frequency controllers. Implementation of real time control.

practical teaching
Demonstration of electrohydraulic servosystem for thrust vector control.
Commissioning of frequency controller.
Commissioning of servo drives.
Commissioning and tune of PID controller.

prerequisite
None

learning resources
Laboratory for industrial automation.

Laboratory for integrated technical systems.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 30
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 30
> auditory exercises: 0
> laboratory exercises: 15
> calculation tasks: 0
> seminar works: 0
> project design: 15
> consultations: 0
> discussion and workshop: 0
> research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 13
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 60
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Astrom K., Wittenmark J., Computer-Controlled Systems: Theory and Design, 2011
Astrom K., Wittenmark J., PID Controllers: Theory, Design, and Tuning, 1995

Intelligent Buildings

ID: MSc-0656
responsible/holder professor: Ristanović R. Milan
teaching professor/s: Ristanović R. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: control engineering

goals
To introduce students to the concept of intelligent buildings, technical systems in modern buildings and control systems technology and their integration.

learning outcomes
The acquired knowledge is used in engineering practice. The student is competent to understand the technical sub-systems in modern buildings, their configuration and mutual integration of electrical and mechanical systems and management concepts.

Student is able to create ETS project and program KNX components.

Student is able to make application schematics of HVAC system, to define signal list and define quote of sensors, actuators and controllers.

theoretical teaching
The definition of intelligent buildings. Technological systems in intelligent buildings. Introduction to digital control systems: analog / digital input / output values, sensors, actuators, digital controllers. Control valves. Basic communication standards and their characteristics. Control algorithms and tuning.

Management of central heating systems. Control of boilers. Control of substations. Outdoor temperature compensation. Central and zone control. Control in the solar system. Managing in the air conditioning. Typical control schemes of air conditioning. Cascade control. Secvential control. Regulation of air humidification. Control of air handling unit with variable flow. Lighting control systems. Lighting control system components, analog / digital control and lighting control strategies. Protection systems and solar radiation and control strategies. Measuring energy consumption. Fire protection systems. Access control systems. Building management systems. Application of Internet technology in control.

practical teaching
Understanding the physical implementation of sensors, digital controllers and drivers. Understanding the physical implementation of control systems in buildings. Programming and networking of digital controllers.

Realization of simple solutions.

prerequisite
Basic automatic control knowledge and digital systems.

learning resources
M. Ristanovic, Intellingeng Buildings, printed lectures

Laboratory

KNX/EIB Trainings Kit

ETS3 - licensed software

number of hours: 75

active teaching (theoretical): 45
lectures: 30
elaboration and examples (revision): 15

active teaching (practical): 15
auditory exercises: 0
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 10
final exam: 30
requirements to take the exam (number of points): 50

references

Тодоровић, Ристановић М, Ефикасно коришћење енергије у зградама, Универзитет у Београду, 2015, ISBN 978-86-7083-875-8
Shengwei Wang, Intelligent Buildings and Building Automation, Spon Press, New York, 2010
H. Merz, T. Hansemann, C. Huebner, Building Automation, Springer-Verlag, Berlin Heidelberg, 2009
C.F. Mueller, Regelungs- und Steuerungstechnik in der Versorgungstechnik, 2002

Intelligent Control Systems

ID: MSc-0657
responsible/holder professor: Jovanović Ž. Radiša
teaching professor/s: Jovanović Ž. Radiša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: control engineering

goals
•Introduction to methods for the analysis and design of intelligent control systems.

•Gaining practical knowledge of several of the main techniques of intelligent control and an introduction to some promising research directions.

•Use of the computer for simulation and evaluation intelligent control systems.

learning outcomes
On successful completion of the course the students should be able to:

•understand of the functional operation of a variety of intelligent control techniques

•understand of control-theoretic foundations,

•Carry out synthesiis and analysis of intelligent control systems based on combinations of various theories: simulation, neural networks, fuzzy systems, genetic algorithms, biologically inspired algorithms , etc.

•use of the computer for simulation and evaluation intelligent control systems through Matlab software, as and practical realization of control algorithms on various control plants using programming software Matlab and LabView.

theoretical teaching
Introduction of intelligent control. Conventional and intelligent control.

Fundamentals of artificial neural networks: architecture, classification, basic properties. Neural network learning rules: principles, Hebbian learning law, Widrow-Hoff learning, delta rule. Single layer feedforward neural networks, perceptron, linear network. Multilayer feedforward networks with backpropagation error. Radial basis function neural networks. Support vector machines. Dynamical neural networks. Neural networks for nonlinear dynamic system modelling and identification. Neural networks for control: direct control and indirect control, direct inverse control,model predictive control. Biologically-inspired algorithms.

practical teaching
PA:

Practical work includes computational exercises that follow the content of course.

PL:

Practice and experiments: computer applications in simulation and evaluation of intelligent control systems, as well as their practical realization using Matlab and LabView for control different plants within a modular educational real-time control system (double inverted pendulum, ball and beam system, DC servo motor).

prerequisite
Defined by curriculum of the study programme.

learning resources

•Radiša Jovanović, Intelligent Control Systems, Lecture notes in electronic form

•Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, 2016.

•Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software,

•PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers,

• Installation for control system testing and acquisition of electrical variables,

•Automatic Control Laboratory, Intelligent Control Systems Laboratory, Control Systems Laboratory.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 10
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Radiša Jovanović, Introduction to Neural Networks and Fuzzy Systems, Lecture notes, Faculty of Mechanical Engineering
Simon Haykin, Neural Networks and Learning Machines, Vol. 3. Upper Saddle River, NJ, USA:: Pearson, 2009.

Linear systems synthesis

ID: MSc-1068
responsible/holder professor: Ribar N. Srđan
teaching professor/s: Ribar N. Srđan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: control engineering

goals
Students meet the basic requirements for the design of control systems and to first in the form of knowledge of basic work indicators as a system in steady state and in transient operating modes. Students meet a wide range of modern methods for the design of real control systems.

learning outcomes
To know, accept and overcome some of the offered method for designing control systems and to be trained to implement them in every particular case, the class studied system. Furthermore it is expected that application of the method of designing control systems that take place in real time on the facilities and processes for a class of linear systems with feedback.

theoretical teaching
Analysis and synthesis system. The criteria for assessing the quality of the system behavior. Requirements in the synthesis. Hal Map and Nicholls diagram. Root locus method in the complex plane. Parametric methods of synthesis system. Algebraic methods. Structural synthesis system. Synthesis of the Bode diagram. Root locus method synthesis. Integral criteria for assessing the quality of the system behavior. The parameter optimization. Conditional optimization. Optimization of state space - Kalman regulator. Synthesis state space - tuning methods poles. Design Observer. Systems Decoupling.

practical teaching
Hal Map and Nicholls diagram. Root locus method in the complex plane. Parametric methods of synthesis system. Algebraic methods. Structural synthesis system synthesis in Bode diagram.Root locus method synthesis. Integral criteria for assessing the quality of the system behavior. The parameter optimization. Conditional optimization. Optimization of state space - tuning methods poles. LABORATORY EXERCISES Synthesis via first order PD subsystem.Kalman's system controller syntehsis.

prerequisite
Automatic control examine passed

learning resources
D. L J. Debeljković, "Examples in the design of linear systems", Faculty of Mechanical Engineering, Belgrade, 1994 R. Milojković, D. L J. Debeljković, "Design of linear systems", Faculty of Mechanical Engineering, Belgrade, 1981, (book), p.363, (extra tutorial, second revised and expanded edition), p.253. D. L J. Debeljković, V. S. Mulić, Synthesis of Linear System Čigoja press, Beograd 2002. D. L J. Debeljković, tuning methods poles PART II, Part II, and Part III, 2005, 2007, 2008. Written copies of the lecture.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0

calculation tasks: 0
seminar works: 6
project design: 4
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 4
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 10
final exam: 30
requirements to take the exam (number of points): 30

references
B. R. Milojković, D. L J. Debeljković, "Design of linear systems", Faculty of Mechanical Engineering, Belgrade, 1981
D. L J. Debeljković, V. S. Mulić, Synthesis of Linear System Čigoja press, Belgrade 2002
Written copies of the lectures

Nonlinear Systems 1

ID: MSc-0628
responsible/holder professor: Jovanović Ž. Radiša
teaching professor/s: Jovanović Ž. Radiša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: control engineering

goals
•Introduction to nonlinearities in the plants and processes.

•Introduction to basic concepts of analysis of nonlinear systems.

•Understanding and using the basic tools for testing the stability of nonlinear systems.

•Analysis of nonlinear systems using Matlab and LabView programming software.

learning outcomes
On successful completion of the course the students should be able to:

Knowledge and understanding of:

•Recognize and understand nonlinear problems and phenomena in the processes and plants.

•Determine mathematical models of nonlinear systems.

•Apply basic methods for analyzing nonlinear systems in time domain and state space.

•Perform simulations, analysis and control of nonlinear systems using software packages Matlab and LabView.

theoretical teaching
Introduction to nonlinear systems and control. Typical nonlinear problems and phenomena. Types of nonlinearity.Types of nonlinear systems. State space. Solution of nonlinear di erential equations, existence and uniqueness of solutions, Lipschitz function, comparison principle. Equilibrium points. Phase-plane analysis: phase portrait, limit cycles, stability domain, classification of singular points.

Poincaré-Bendixson criterion. Lyapunov stability concepts. Lyapunov stability and instability theorems of equilibrium points. LaSalle's theorem, invariance principle and Chetaev’s theorem. Lyapunov’s direct and indirect methods. Krasovski's criterion.

practical teaching
PA:

Nonlinear mathematical models of dynamic systems. Determination of equilibrium points. Phase-plane analysis: phase portrait, limit cycles, stability domain, stability and attraction of equilibrium points. Determining the system stability by applying indirect and direct method of Lyapunov.

PL:

Practice and experiments: verification of non-linear mathematical models of different objects using a PC; experimental determination of nonlinear static characteristics and analysis of the dynamic behavior of different objects of automatic control (DC servo motor, heat flow experiment, coupled tanks experiment) using the programming software Matlab/Simulink and LabView.

prerequisite
Defined by curriculum of the study programme.

learning resources

•Lj.Grujić, D.Lazić, Nonlinear Systems, Lecture notes in electronic form

•Radiša Jovanović, Nonlinear Systems 1, Lecture notes

•Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, 2016.

•Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software,

•Electrohydraulic control system,

•PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers,

• Installation for control system testing and acquisition of electrical variables,

•Automatic Control Laboratory, Intelligent Control Systems Laboratory, Control Systems Laboratory.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Hassan K. Khalil, Nonlinear Systems, 3rd Edition, Prentice-Hall, 2002.
Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Englewood Cliffs, NJ: Prentice-Hall, 1991.

Nonlinear Systems 2

ID: MSc-0609
responsible/holder professor: Jovanović Ž. Radiša
teaching professor/s: Jovanović Ž. Radiša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: control engineering

goals

•Building the foundations of nonlinear control design and analysis.

•Introducing commonly used nonlinear control tools.

•Analysis and control of nonlinear systems using Matlab and Labview programming software.

learning outcomes

On successful completion of the course the students should be able to:

•Perform basis of dynamical analysis of certain classes of nonlinear systems.

•Apply various methods for testing the system stability by Lyapunov techniques and input-output analysis.

•Understand and use diferent control techniques of nonlinear systems.

•Perform simulations, analysis and control of nonlinear systems using software packages Matlab and LabView.

theoretical teaching

Lurie's direct and indirect control systems. Linear and Aizerman Conjecture. Absolute stability. Popov's and Circle criteria. Tsypkin's trasnformation. Exact (feedback) linearization. Input-state linearization. input-output linearization. Zero dynamics and input-to-state stability. L2 gain and small gain theorem. Sliding mode control. Backstepping. Gain scheduling. Approximate methods. Describing function analysis. Modified Nyqiust criteria.

practical teaching

PA:

Practical work includes computational exercises that follow the content of course:

stability of Lurie direct and indirect systems; дегermination stability of nonlinear systems using linear and Aizerman conjecture; Popov's and circle criteria; exact (feedback) linearization: input-state linearization, input-output linearization; zero dynamics and input-to-state stability; sliding mode control: backstepping:gain scheduling; describing function analysis; modified Nyqiust criteria.

PL:

Application programming languages C and Matlab in the analysis, simulation and control of nonlinear systems.

Practice and experiments: analysis, design and simulation of nonlinear systems; experimental application of nonlinear control algorithms using the PC and the software Matlab/Simulink and LabView on different control plants (DC servo motor, inverted pendulum, coupled tanks experiment, ball and beam system).

prerequisite

Defined by curriculum of the study programme.

learning resources

•Lj.Grujić, D. Lazić, Nonlinear systems, Lecture notes in electronic form

•Radiša Jovanović, Nonlinear systems 2, Lecture notes

•Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade,

•Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software,

•Electrohydraulic control system,

•PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers,

• Installation for control system testing and acquisition of electrical variables,

•Automatic Control Laboratory, Intelligent Control Systems Laboratory, Control Systems Laboratory.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Hassan K. Khalil, Nonlinear Systems, 3rd Edition, Prentice-Hall, 2002.
Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Englewood Cliffs, NJ: Prentice-Hall, 1991.

Skill Praxis M - SAU

ID: MSc-1214
responsible/holder professor: Ristanović R. Milan
teaching professor/s: Jovanović Ž. Radiša, Lazić V. Dragan, Ribar N. Srđan, Ristanović R. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: control engineering

goals
Practical experience and stay student in an environment where will realize his professional career. Identifying the basic functions of the business system in the field of product development, production and use as well as the role and tasks of mechanical engineers in such a business system.

learning outcomes
After completion of the Professional training - M - SAU, students should gain insight into the practical aspects of the innovative and creative work of engineers in the next.

- In recognition of the basic functions of the business system in the field of TS development, production and use of TS as well as the role and tasks of engineers in such a business system.

- The manner of organization and functioning of the environment in which it will apply the acquired knowledge in their future professional career or entrepreneurial work.

- The models of communication and flows in the development and implementation of product and market realization.

- In recognition of the basic processes in engineering design, manufacture and maintenance of TS.

theoretical teaching
Introduction, aim, content activity.

practical teaching
Practical work means work in organizations where they perform various activities in connection with mechanical engineering. The choice of thematic units and commercial and research organizations carried out in consultation with the subject teacher. In principle, the student can carry out the practice in manufacturing organizations, project and consulting organizations, organizations dealing with maintenance of mechanical equipment, public utility companies and one of the laboratories at the Faculty of Mechanical Engineering. The practice may also be made abroad. During the practice students have to keep a diary in which to enter a description of the tasks they perform, the conclusions and observations. After completed practice must make a report that will defend in front of the subject teacher. The report shall be submitted in the form of a seminar paper.

prerequisite
-

learning resources
Organizations that includes life-cycle product development, production, use.

-Organizations engaged in product development.

-Industrial Companies whose business is making products in mechanical engineering.

-Industrial Companies whose business is based on the use of mechanical systems.

-The companies whose activity is distribution and maintenance of machines and components.

number of hours: 90

active teaching (theoretical): 2
lectures: 2
elaboration and examples (revision): 0

active teaching (practical): 78
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
consultations: 0
discussion and workshop: 0
research: 48

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 50
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references

ENGINEERING MATERIALS AND WELDING, TRIBOLOGY, FUELS AND COMBUSTION

Biofuels in combustion processes

ID: MSc-0894
responsible/holder professor: Manić G. Nebojša
teaching professor/s: Jovanović V. Vladimir, Manić G. Nebojša, Stojiljković D. Dragoslava
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals

Types of biofuels and their classification. Characterization of solid, liquid and gaseous biofuels. Modern procedures of analysis and characterization. Biofuels standardization. Solid, liquid and gaseous biofuels - modern procedures of production and application. Importance of biofuels from the environmental point of view, sustainability criteria. Basics of calculations of combustion process and pollutant emissions. Phases of combustion and basics of modeling. Modern systems for biofuels combustion. Possibilities for utilization of mixtures of biofuels and fossil fuels in the combustion processes. Future development of biofuels.

learning outcomes

Upon the succesful completition of this course students will be able to:

1. overview of directives and regulations for promotion of use as well as potential of different biofuels in Serbia

2. define resources and properties of plant raw materials for biofuels production.

3. Have an advanced understanding of biofuel and biomass production.

4. Perform technical, economic and environmental comparisons of various energy systems.

5. Critically appraise logistical issues associated with implementing large scale biofuel and biomass energy production.

6. Apply sustainability criteria to various energy systems and evaluate the results.

7. Evaluate the potential of different fuels and energy technologies.

8. be able to better predict the consequences of their energy choices as the next generation of energy users.

theoretical teaching

Biofuels (pellets, briquettes, wood chips, bioethanol, biodiesel, biogas etc.) and basic characteristics. Specific characteristics of biofuels related to the fossil fuels. Raw materials and production methods. Possibilities for biofuels utilization (stoves, boilers, IC engines). Influence of biofuels characteristics on selection of the best available technology for combustion. Calculation of the combustion process and phases of biofuels combustion. Modern equipment for biofuels combustion. Biofuels and environment.

practical teaching

Basics of biofuels characterization and specific characteristics related to the fossil fuels. Characterization of solid fuels. Recalculation from one to another mass basis for solid biofuels. Characterization of liquid biofuels. Characterization of gaseous biofuels. Determination of biofuels heating value, calculation method and experimental method. Elements of stoichiometry and determination of pollutants emission from combustion process. Determination of physical and chemical characteristics of the liquid biofuels. Basics of modeling of biofuels combustion process. Basics of measurements in modern combustion systems for biofuels combustion.

prerequisite
No special requirements.

learning resources
Loo S., Koppejna J.: The Handbook of Biomass Combustion & Co-firing, Earthscan, 2007; Rutz D., Janssen: BioFuel Technology Handbook, Intelligent Energy Europe, 2007.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 18
calculation tasks: 4
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 10
calculation tasks: 5
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
Loo S., Koppejna J.: The Handbook of Biomass Combustion & Co-firing, Earthscan, 2007
Rutz D., Janssen: BioFuel Technology Handbook, Intelligent Energy Europe, 2007.

Combustion and sustainable development M

ID: MSc-1145
responsible/holder professor: Milivojević M. Aleksandar
teaching professor/s: Milivojević M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: engineering materials and welding, tribology, fuels and combustion

goals
In the light of the fact that currently over 90% of world energy demand is produced by combustion processes, and that in the coming decades is expected that combustion will be the predominant technology for energy production, with a share of over 65%, this course is designed, keeping in mind that the main goal is to prepare students to work in the area of sustainable development and energy, to provide better understanding, accept the findings and enable students to competently participate in solving the problems of sustainable development.

learning outcomes
After successful completion of this course, students should be able to:

- analyze the challenges posed by the new scenario of the problem of energy and sustainable development,

- master the obtained knowledge to an extent that would allow them to apply combustion technology in both existing and future energy systems and technologies,

- apply the acquired knowledge in this field in the industry and energy sectors,

- work in research and development organizations.

theoretical teaching
The problem of energy. Energy sources. Fossil fuels, renewable energy sources, industrial and municipal waste. Environmental aspects - pollution of air, water and land. Basics of the combustion process. Material and energy balances. Specifics of burning different types of fuel. The impact on the environment. The concept of sustainable development. Complex systems. Sustainable development in terms of the developed countries. Specifics for developing countries. Energy processes and devices based on combustion. New technologies.

practical teaching
Practical training shall include practical exercises, laboratory exercises, computational tasks and seminars.

Within auditory exercises will be done more examples of material and energy balance of the combustion process and pollutants, as well as the explanation of the principle of measuring emissions of combustion products. Laboratory classes will include measurements of emissions of polluting components from the combustion process. In the framework of the computational task, students will do an individual task in connection with the material and energy balance of a combustion fuel. Seminar will cover the analysis of the introduction of alternative energy sources, more favorable from the standpoint of sustainable development in a particular energy device or process.

prerequisite
None.

learning resources
Handouts.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 5
seminar works: 5
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 3
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 3
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 10
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
A. Milivojevic, Subject handouts
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE

Combustion appliances

ID: MSc-1147
responsible/holder professor: Milivojević M. Aleksandar
teaching professor/s: Milivojević M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: engineering materials and welding, tribology, fuels and combustion

goals
The objective of this course is to provide students with general appliances that use combustion methods.

learning outcomes
To teach and enable students to understand general combustion appliances and use the knowledge in industrial and energy sectors.

theoretical teaching
The combustion appliances include burners, burner systems, combustors, furnaces and control systems. Different types of burners including diffusion, atmospheric, premixed with natural and force aerated, porous and thermal radiation types. Mixture preparation for liquid, gaseous and solid fuel types, flame stabilization methods, standards, safety systems.

practical teaching
Displaying techniques for controlling the operation of various combustion devices.

prerequisite
No preconditions for attendance

learning resources
Subject Handouts.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 5
seminar works: 5
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 2
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 3
final exam: 3

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 20
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

A. Milivojevic, Subject handouts
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE
Warnatz J., Mass U., Dibble R. Combustion, 2006.

Combustion for propulsion systems

ID: MSc-1144
responsible/holder professor: Milivojević M. Aleksandar
teaching professor/s: Milivojević M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: engineering materials and welding, tribology, fuels and combustion

goals
Propulsion systems are mostly based, except a few exceptions, on liberated energy in combustion processes. The goal of the "Combustion for Propulsion Systems" is to enable a student deeper understanding of combustion processes and to qualify them to take part in analyses, development and application of propulsion systems.

learning outcomes
After successful completion of this course, studenty should be able to:

- analyze existing and future propulsion systems regarding combustion,

- apply the acquired knowledge in the design and development of propulsion systems,

- work in scientific and research organizations in areas of propulsion and combustion.

theoretical teaching
Combustion and energy conversion systems. Conservation laws. Fuels and propellants. Elements of stoichiometry. Thermochemistry and processes. Chemical kinetics. Heat and mass transfer. Diffusion flames. Premixed laminar and turbulent flames. Liquid propellants combustion. Solid rocket propellants combustion. Detonation. Instabilities. Microcombustion. Combustion in supersonic flows.

practical teaching
Practical tuition includes numerical analysis of examples of conservation laws, stoichiometry, thermochemistry and chemical kinetics. Experimental research includes diffusion and premixed flame and burner characterization. A student will numerically solve a problem in propulsion combustion.

prerequisite
None

learning resources
The subject Handouts.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 24
> elaboration and examples (revision): 6
>
> **active teaching (practical):** 30
> auditory exercises: 10
> laboratory exercises: 5
> calculation tasks: 5
> seminar works: 5
> project design: 0
> consultations: 5
> discussion and workshop: 0
> research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 2
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 3
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 10
calculation tasks: 15
seminar works: 5
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
A. Milivojevic, Subject handouts
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE
Williams, F.A.: Combustion Theory (second edition) Addison-Wesley Publishing Company, 1985.

Combustion M

ID: MSc-0971
responsible/holder professor: Stojiljković D. Dragoslava
teaching professor/s: Jovanović V. Vladimir, Manić G. Nebojša, Stojiljković D. Dragoslava
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
Fundamentals of thermodynamics of the combustion process, general terms, material and energy balance of the process. Fundamentals of chemical statics and kinetics of thermal processes. Physical and physical-chemical phenomena in the combustion process. Specific features of combustion of solid, liquid and gaseous fuels. Combustion appliances. Environmental aspects of combustion.

learning outcomes
Mastering the techniques of calculation of material and energy balance of the combustion process. Mastering the techniques of flame investigation. Acquiring knowledge on the control of the combustion efficiency. Acquiring knowledge about the impact of combustion products on the environment.

theoretical teaching
Fundamentals of thermodynamics of the combustion process, general terms, material and energy balance of the process. Fundamentals of chemical statics and kinetics of thermal processes. Chemical equilibrium, the speed of chemical reactions. Physical and physical-chemical phenomena in the combustion process. The phenomena of ignition and self-ignition. Specific features of combustion of solid, liquid and gaseous fuels. Combustion appliances for different fuels. Environmental aspects of combustion. The causes, mechanisms of toxic components and the possibility of prevention. The measures and procedures for reduction of toxic emissions.

practical teaching
Chemical kinetics, chemical equilibrium problem solving and speed of chemical reactions in combustion. Dissociation products of combustion, the calculation of the amount and composition of the products of combbustion and combustion temperature. Incomplete combustion, determination of the amount and composition of the products of combustion and combustion temperature. Length of laminar flames, influential properties, experimental determination. The boundaries of stable combustion, the definition and experimental determination. Ignition limits (concentrations). Flame front propagation speed.

prerequisite
No special requirements.

learning resources
Milan Radovanovic: Fuels; Milan Radovanovic: Industrial water; Aleksandar Rac: Lubricants; D. Draskovic, M. Radovanovic, M. Adzic: Combustion; M. Adzic, A. Rac, S. Memetović: Manual for laboratory exercises in the Fuels, M. Radovanovic: Manual for laboratory exercises in the combustion

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 20

calculation tasks: 2
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 40
laboratory exercises: 10
calculation tasks: 5
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Design of Welded Structures

ID: MSc-0898
responsible/holder professor: Radaković J. Zoran
teaching professor/s: Radaković J. Zoran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
After having completed the course, along with the theory and practical classes (through problems and calculation exersizes, seminars etc.), the student acquires the proper academic knowledge and skills in the field of weld design, and stress state analysis of the welded structure. The welded structures of interest are made of steel and aluminium alloys. In addition to the static calculation and design of welded structures, other fields of design include cases of fatigue loading, as well as dynamic loads. Particular design cases also include modern methods in evaluating the residual stresses and strains. Candidates shall be familiar with, and be able to apply their knowledge to real welded structures in exploitation. They should be familiar with modern scientific papers in the field, and are able to fully understand and keep track of scientific articles.

learning outcomes
Upon the successful completion of the course, the students are able to:

• Identify the loading types of welded structures

• Analyze the stress state of the welded structure (also with the presence of complex loads)

• Solve specific problems of calculating welded structures with both fillet and butt welded joints

• Solve complex stress states, that evolve from a combination of different loading types (tension, bending, shear, torsion, restrained torsion) in both static and dynamic conditions

• Solve problems in the calculation of fatigue loaded welded structures

• Solve problems in the calculation of dynamically loaded (impact) welded structures

• Solve problems in the calculation of welded structures with characteristic member sections – light-weight structures with thin cross sections, both open- and closed profile contour sections

• Solve the implications that may arise in cases of poor design, or as a result of material structural damage

• Connect the acquired knowledge from this field to the knowledge from other fields: engineering materials, mechanics, strength of materials, structural resistance, metal structures, welding technology, with applications in practice

theoretical teaching
Introduction. Theoretical basis of welded structures. Strength of materials basics. The basics of weld and structural design. Behaviour of welded structures at various types of loading. Design of welded structures in static loading conditions. Design of welded structures in dynamic (fatigue) loading conditions. Stress and strain states. Modern methods for measuring i determining the residual stress and strain state in the welded structure.

practical teaching
Static calculation and design of welded structures. Dynamic calculation and design of welded structures. Problem solving, examples, exercises. Application of standard codes for evaluating stress states at various loading types. Calculation of stress and strain states. Deformation and stress measurements.

Tensometry and its application to welded structures. Examples of tensometric applications on welded structures with a retrospective view on some existing problems in practice.

prerequisite
Attended lectures and exercises: Strength of Materials, Mechanics, Resistance of Structures, Basics of Welding, and Engineering Materials 1 and 2.

learning resources
1. Z. Petkovic, D. Ostric, Metallic Structures in the Machine Building Industry 1, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 1996 (or later). (in Serbian)

2. Z. Perovic, Welded Structures, University of Montenegro, Faculty of Mechanical Engineering, Podgorica, 2002 (or later) (in Serbian)

3. D. Ruzic, Strength of Structures, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)

4. Strength of Materials - Tables, Chair/Cabinet of the Theory of Structures, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2000. (in Serbian)

5. Scripts/handouts from class lectures and exercises, and presentations in electronic format.

6. Internet resources.

number of hours: 75

active teaching (theoretical): 30
lectures: 25
elaboration and examples (revision): 5

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 10
seminar works: 10
project design: 0
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 2
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 15
seminar works: 10
project design: 0
final exam: 40
requirements to take the exam (number of points): 40

references

Z. Petković, D. Ostrić, Metalne konstrukcije u mašinogradnji 1, izd. Univerzitet u Beogradu, Mašinski fakultet, Beograd, 1996.

Z. Perović, Zavarene konstrukcije, izd. Univerzitet Crne Gore, Mašinski fakultet, Podgorica, 2002

O.W. Blodgett, Design of Welded Structures, Publ. The James F. Lincoln Arc Welding Foundation, 1966.

T. Lassen, N. Récho, Fatigue Life Analyses of Welded Structures, ISTE Ltd, 2006.

Recommandations concernant les structures soudées en aluminium et alliages Al-Mg: doc. IIS/IIW-398-72 - révisé, Institut international de la soudure, Ed. 2, Publications de la Soudure Autogène (1980)

Ecology of combustion

ID: MSc-1146
responsible/holder professor: Milivojević M. Aleksandar
teaching professor/s: Milivojević M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: engineering materials and welding, tribology, fuels and combustion

goals
More than 90% of the world's energy consumption is produced by combustion. It is expected that combustion will still be a prevailing method for energy production in the coming decades. On the other hand, having in mind that combustion is by far the biggest source of pollution, the goal of subject is to enable better understanding of the topic, train and qualify students to become competent experts in this field of international key importance.

learning outcomes
After successful finishing the course students should be able to:

- recognize and use modern technologies of the combustion processes,

- use techniques for reduction of emission of harmful and polluting combustion products,

- apply the acquired knowledge in combustion in the industry and energy sectors,

- work in research and development organizations.

theoretical teaching
Combustion basics.Conservation of mass and enery.

Specific topics on combustion of different fuels.

Combustion facilities and their performance.

Biofules.

Co-combustion.

Emissions of polluting and harmful contaminants.

Role of CO2.

Technics to reduce emission of NOx.

Technics to reduce emission of SO2.

Technics to reduce emission of CO and HC.

Technics to reduce emission of particulates.

Technics to reduce emission of heavy metals

Technics to reduce emission of CO2.

CO2 trading.

New technologies. Fuel cells. Hydrogen.

practical teaching
Practical tuition includes analysis and examples of conservation of mass and enery laws regardding combustion and emissions. Examples of technics to reduce emissions of NOx and SO2 will be treated in particular. Measurements of flue gas emission components will be performed in a purpose built test

stand. The effect of influencing parameters on emission performance of a purposely built burner will be experimentally performed and analyzed. A student will theoretically and numerically solve a problem of mass and energy balance of one of pollution reduction techniques.

prerequisite
No conditions

learning resources
Subject Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 3
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 10
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
A. Milivojevic, Subject handouts
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE

Engineering materials 3

ID: MSc-0892
responsible/holder professor: Bakić M. Gordana
teaching professor/s: Bakić M. Gordana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written+oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
The aim of this course is to introduce students to different types of engineering materials and their properties with the goal of understanding and studying the possibility of their application for manufacturing of different elements and constructions. Special attention is devoted to studying the influence of composition, thermical proccesing and processing by plastic deformation on the structure and properties of the material. This course enables possible collabortions with institutes, companies and factories that make and construct engineering materials and deal with their application.

learning outcomes
Upon the successful completion of the course, students are able to:

- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;
- determine the potential causes of damage;
- perceive the eventual possibilities for preventing the occurrence of damage;
- define the testing programme for detecting damages in mechanical structures;
- prescribe maintenance measures for preventing damage in mechanical structures;
- relate the acquired knowledge to other fields, with practical applications.

theoretical teaching
Advanced course of Engineering materials. Ferrous and non-ferrous engineering materials and their clasification. Carbon steels, modern steel making processes, ingot casting, casting microstructure, hot and cold working of carbon steels, classification of plane carbon steel, heat treatment, microstructure and properties. Microalloyed steels, precipitation mechanisms, strengthening. Dual-phase steels. Effects of alloying elements on microstructure and properties of alloy steels. Hardenability. Classification of alloy steels. Temper embrittlement in low-alloy steel. Maraging steels. Classification of stainless steels according microstructure, ferritic, martensitic, austenitic, precipitation-hardening stainless steels and duplex stainless steels. Tool steels, classification and properties. High-speed tool steels. Nickel, applications, microstructure, properties. Nickel-based alloys, composition, applications, microstructure, properties.

practical teaching
Aluminium and its alloys. Classification of aluminium alloys, chemical composition, applications, microstructure, properties. Water-hardening tool steels. Hot-work tool steels. Secondary hardening of tool steels. Heat treatment of high-speed tool steels. Powdered alloy, sintering. Superalloys. Casting of superalloys. Problems and tasks: calculation of microstructural phase fractions, engineering designing with alloy steels and aluminium steels properties. Titanium and its alloys, applications, microstructure, properties. Magnesium and zinc alloys. Copper alloys.

prerequisite
Necessary conditions: Engineering materials 1 and 2.

Desired condition: Physics and Strength of material.

learning resources

1. L. Šiđanin, Mašinski materijali 2, FTN-Novi Sad, 1996, KDA
2. Šuman H., Metalografija, TMF - Beograd, 1981, KDA

number of hours: 45

active teaching (theoretical): 12
lectures: 12
elaboration and examples (revision): 0

active teaching (practical): 27
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 7
seminar works: 8
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 2
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 0
calculation tasks: 15
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

W.D.Callister: Materials Science and Engineering, An Introduction, 2000, John Wiley, NewYork
W.Smith: Structure and Properties of Engineering Alloys, 1993, McGrow-Hill,Inc

Fracture Mechanics and Structural Integrity

ID: MSc-1339
responsible/holder professor: Radaković J. Zoran
teaching professor/s: Radaković J. Zoran, Sedmak S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
Objectives of this course are that students, after completing theoretical basic training in fracture mechanics, and with their maximum involvement in practical training (through laboratory exercises, development of computational tasks, writing seminar papers, etc..), become competent in the field of structural integrity and gain appropriate academic skills, and also develop specific creative and practical skills that are needed in professional practice.

learning outcomes
By attending this course, provided by the curriculum of the subject, the student will be able to solve particular problems of structural integrity, and to examine the possible consequences that may occur in case of bad solutions. The student will also able to link their knowledge in this field with other areas and apply them in practice.

theoretical teaching
Theoretical classes: Introduction. Basics of fracture mechanics. Stress and strain in the cracked body. Elastic and elastic-plastic fracture mechanics. Fracture mechanics parameters. Stress intensity factor, crack tip opening, J integral. Application of fracture mechanics in structural integrity. Welds as a place of origin of the cracks. Integrity of welded structures. Assessments in the field of elasticity and elasto-plasticity. The crack growth force in relation to the material tensile curve.

practical teaching
Practical classes: Determination of fracture mechanics parameters in elastic and elastic-plastic field. Experimental, numerical and analytical methods. Standard procedures for measuring parameters of fracture mechanics, as well as material properties. Chart analysis of fracture and its application to welded joints and construction. Assessment of structural integrity of the given construction example by using all acquired knowledge. Consultation.

prerequisite
required:Materials strength, Mechanics, Fundamentals of structure integrity, Basic of Welding Process and Mechanical materials 1 and 2

learning resources
[1] Written lessons from lectures (handouts)

[2] A. Sedmak, Use of the fracture mechanics on the structure integrity assessment, Faculty of Mechanical Engineering, Belgrade, 2003.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 25
auditory exercises: 10
laboratory exercises: 0

calculation tasks: 10
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 3
research: 0

knowledge checks: 20
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 30
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references
T.L. Anderson, Fracture Mechanics: Fundamentals and Applications, 3rd ed, CRC Press, London, 2005.
R.W.Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, New York, 1996.

Fuel, Lubricants and Industrial Water 2

ID: MSc-0893
responsible/holder professor: Jovanović V. Vladimir
teaching professor/s: Jovanović V. Vladimir, Manić G. Nebojša, Stojiljković D. Dragoslava
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: engineering materials and welding, tribology, fuels and combustion

goals
Fuel types. Stoichiometric combustion equations. Combustion temperature. Characterization of solid fuels, technical and fundamental analysis. Solid fuel origins, derivation, applications. Liquid fuels, origins, derivation, applications. Gaseous fuels, origins, derivation, applications. Lubricants, types and main characteristics, applications. Industrial water, types and properties. Essential characteristics of the water for industrial purposes. Problems in the use of natural waters. Water treatment for industrial applications.

learning outcomes
Upon completion of this course students should be able to:

1 Define the concept of fuel, the criteria for the characterization of fuel and fuel types according to the adopted criteria, calculate the amount and composition of the combustion products and combustion temperature.

2 Define basic characteristics of solid fuels: moisture content, mineral content, the volatile content, carbon residue content, heating value.

3 Define basic characteristics of liquid fuel: behavior at elevated temperatures, behavior of low temperatures, density, water content and mechanical impurities, volatility, viscosity, resistance to detonation and inflammability.

4 Define the role of lubricants in engineering and basic characteristics of them

5 Define the role of water for industrial applications and the most important characteristic: hardness and acidity.

theoretical teaching
The concept of fuel. Fundamentals of combustion, the stoichiometric equations. Calculation of the quantity and composition of combustion products. The combustion temperature, types and methods of calculation. Solid fuels, origins, procedures for derivation and application. Liquid fuels, origins, procedures for derivation and application. Gaseous fuels, origins, procedures for derivation and application. Lubricants: lubricants types, main characteristics relevant for application, the application of lubricants. Industrial water: water types and basic characteristics. Preparation of water for industrial applications, methods.

practical teaching
The conversion from one to another mass of solid fuel. Calculation of heating value of the fuel. Elements of stoichiometry. Combustion temperature . Determination the characteristics of proximate analysis of solid fuels. Determination of heating value of solid and liquid fuels with a bomb calorimeter and the determination of heating value of gaseous and liquid fuels with Junkers calorimeter. Determination of the distillation curve. The significance of the main temperature on distillation curve. Characteristics of fuels at elevated and reduced temperatures. Quality control. Determination of the viscosity of liquid fuels and lubricants (dynamic, kinematic viscosity and relative). Determination of the basic characteristics of grease. Determination of water hardness and acidity.

prerequisite
No special requirements.

learning resources
Milan Radovanovic: Fuels; Milan Radovanovic: Industrial water; Aleksandar Rac: Lubricants; M. Adzic, A. Rac, S. Memetović: Manual for laboratory exercises in Fuels;

number of hours: 30

active teaching (theoretical): 15
lectures: 8
elaboration and examples (revision): 7

active teaching (practical): 10
auditory exercises: 1
laboratory exercises: 9
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 2
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 10
calculation tasks: 5
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 20

references

Skill Praxis M - ZZK

ID: MSc-1340
responsible/holder professor: Prokić-Cvetković M. Radica
teaching professor/s: Bakić M. Gordana, Đukić Z. Miloš, Popović D. Olivera, Prokić-Cvetković M. Radica, Radaković J. Zoran, Sedmak S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: project design
parent department: engineering materials and welding, tribology, fuels and combustion

goals
Objectives of this course are that students, after completing theoretical training, are prepared for their maximum involvement in practical training. Objective is that students become competent in the field of welding and gain appropriate academic skills, and also develop specific creative and practical skills that are needed in professional practice.

learning outcomes
By attending this course, provided by the curriculum of the subject, the student will be able to solve particular problems from practice, and to examine the possible consequences that may occur in case of bad solutions. The student will also able to link their knowledge from various fields and apply them in practice.

theoretical teaching
Introducing students to problems in practice.

practical teaching
Professional practice performance in the selected individual firms. Writing a report after practice.

prerequisite
required:Mechanical materials 1 and 2

learning resources
[1] Written lessons from lectures (handouts)

[2] Plavšić N., Šijački-Žeravčić V., Stamenić Z.: Tables of mechanical materials, profiles, sheets and wires, Faculty of Mechanical Engineering, Belgrade, 2004;

[3] Excerpts from the standard

number of hours: 90

active teaching (theoretical): 10
lectures: 0
elaboration and examples (revision): 10

active teaching (practical): 70
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 0

references

Tribological systems

ID: MSc-0537
responsible/holder professor: Vencl A. Aleksandar
teaching professor/s: Vencl A. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
The student attending this course should:

• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);

• Master the calculation methods for tribological elements using the modern lubrication theories;

• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.

learning outcomes
Based on the mastered knowledge the student is qualified to:

• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;

• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;

• Propose the solutions for problems originate from the friction and wear process;

• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;

• Applies methods for the calculation of working and tribological characteristics of considered tribological system;

• Select materials, lubricants and lubrication mode for the considered tribological systems.

theoretical teaching
• Definition of the tribological systems; Tribological characteristics of the mechanical systems.

• Bearings – purpose and types; Preliminary selection of bearing types; Reynolds equation.

• Sliding bearings (hydrodynamic, hydrostatic, sintered and self-lubricated); Calculation of: friction, minimum lubricant film thickness, lubricant flow, bearing load and oil or surface temperature; Selection of lubricants and lubrication procedures.

• Roller bearings; Calculation of: friction, minimum lubricant film thickness and oil temperature; Selection of lubricants and lubrication procedures.

• Gear pairs tribology – the influence of lubrication on the reliability and efficiency; Calculation of: friction, minimum lubricant film thickness, oil temperature, etc.; Selection of lubricants and lubrication procedures.

• Cam mechanisms tribology – materials and tribological characteristics; Selection of lubricants and lubrication procedures.

• Elements with reciprocating linear motion (piston-piston ring-cylinder system, slide ways and guides) – materials and tribological characteristics; Selection of lubricants and lubrication procedures.

• Dynamic seals – type, purpose and materials; Calculation of the tribological characteristics; Selection of lubricants and lubrication procedures.

practical teaching

• Lubricants – role, type, classification and basic properties; Rheology of lubricants; Forms and types of lubrication.

• Examples for sliding bearings (hydrodynamic, hydrostatic, sintered and self-lubricated) tribological characteristics calculation.

• Examples for rolling bearings tribological characteristics calculation.

• Examples for gear pairs and cam mechanisms tribological characteristics calculation.

prerequisite

No special requirements.

learning resources

1. --, Handouts for each lecture.

2. A. Rac, Fundamentals of Tribology, Faculty of Mechanical Engineering, Belgrade, 1991, (in Serbian).

3. A. Rac, Lubricants and Machine Lubrications, Faculty of Mechanical Engineering, Belgrade, 2007, (in Serbian).

4. A. Rac, A. Vencl, Sliding Bearing Metallic Materials – Mechanical and Tribological Properties, Faculty of Mechanical Engineering, Belgrade, 2004, (in Serbian).

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 17
consultations: 13
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40

laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 30
requirements to take the exam (number of points): 35

references

D. Dowson, G.R. Higginson, Elasto-hydrodynamic lubrication, Pergamon Press, Oxford, 1977.
T.A. Harris, Rolling Bearing Analysis, John Wiley & Sons, New York, 1984.
R.J. Welsh, Plain Bearing Design Handbook, Butterworths, London, 1983.
W.B. Rowe, Hydrostatic and Hybrid Bering Design, Butterworths, London, 1983.
W.A. Gross (Ed.), Fluid film lubrication, John Wiley & Sons, New York, 1980.

Tribology

ID: MSc-0519
responsible/holder professor: Vencl A. Aleksandar
teaching professor/s: Vencl A. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
The student attending this course should:

• Comprehend the significance of friction, wear and lubrication (tribology keywords) and the problems connected with it, the field of construction and maintenance of mechanical parts and systems;
• Master the fundamental knowledge in these areas of tribology in order to decide the merits of the choice of materials and lubricants for the construction and tribological components;
• Solve problems related to the prevention of wear and competently decide on techniques to improve tribological properties of materials and lubrication technologies.

learning outcomes
Based on the mastered knowledge the student is qualified to:

• Identifies and critically analyze the basic causes of energy and material dissipation in some mechanical system;
• Recognize the dominant type of wear in some mechanical system and to propose appropriate measures for its reduction;
• Choose the appropriate type of material for the basic tribological elements (plain bearings, roller bearings and gears);
• Describes and distinguishes the most common surface modification and coating deposition methods;
• Explain the influences of temperature and pressure on the value of the viscosity (lubricants rheology);
• Describes and distinguishes the basic types and methods of lubrication with their characteristics.

theoretical teaching
• Tribology as a science and technical disciplines and techno-economical importance of tribology.
• Properties of surfaces and the nature of contact of two bodies.
• Friction – the basic causes and principles; Friction of metals and non-metals.
• Wear – mechanisms and types; Wear calculation and measuring methods; Wear prevention.
• Tribological materials (types and application in tribology); Characteristics and selection of materials for tribological components.
• Technologies for improving the tribological properties of materials (surface modifications and coatings).
• Lubricants – role, type, classification and basic properties; Rheology of lubricants.
• Forms and types of lubrication; Hydrostatic, hydrodynamic, elastohydrodynamic and boundary lubrication.
• Lubrication systems (tasks and roles; procedures and classification; elements definition) and lubricants selection.
• Lubrication services organization and lubricants ecology.

practical teaching

• Tribological losses in the industry and transportation; Tribological improvements studies.

• Characterization of the tribological surfaces; Methods and apparatus for surface roughness measuring; Surface roughness standards; Influence of material processing and machining on the surface roughness; Properties of surface layers.

• Presentation of worn surfaces and machine parts failure due to wear, and wear products (debris).

• Examples of different solutions for improving the tribological properties of materials.

• Laboratory practice: "Experimental evaluation of roughness, friction and wear"; Measuring of roughness and coefficient of friction and wear values for different materials and test conditions.

• Classifications and specifications of lubricants; Methods for lubricants testing.

• Laboratory practice: "Experimental investigation of the rheological properties of lubricants"; Determination of the rheological properties of lubricating oils (viscosity, viscosity-temperature dependence, viscosity index) and greases (shear stress and shear rate gradient, apparent viscosity).

• Essay writing.

prerequisite

No special requirements.

learning resources

1. --, Handouts for each lecture.

2. A. Rac, Fundamentals of Tribology, Faculty of Mechanical Engineering, Belgrade, 1991, (in Serbian).

3. A. Rac, Lubricants and Machine Lubrications, Faculty of Mechanical Engineering, Belgrade, 2007, (in Serbian).

4. A. Rac, A. Vencl, Sliding Bearing Metallic Materials – Mechanical and Tribological Properties, Faculty of Mechanical Engineering, Belgrade, 2004, (in Serbian).

5. Pin-on disc tribometer; Block-on-ring disk tribometer; Four Ball machine.

6. Viscometer for liquid lubricants; Pressure grease viscometer.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 12
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 13
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 4
check and assessment of projects: 0

colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 45
laboratory exercises: 10
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

B. Ivković, A. Rac, Tribology, Yugoslav Tribology Society, Kragujevac, 1995 (in Serbian).
J. Halling, Principles of Tribology, The MacMillan Press Ltd., London, 1975.
D.F. Moore, Principles and Applications of Tribology, Pergamon Press, Oxford, 1975.
B. Bhushan, Principles and Applications of Tribology, John Wiley & Sons, New York, 1999.
A.R. Lansdown, Lubrication – A Practical Guide to Lubricant Selection, Pergamon Press, Oxford, 1982.

Tribotechnique

ID: MSc-0509
responsible/holder professor: Vencl A. Aleksandar
teaching professor/s: Vencl A. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
The student attending this course should:

• Master the fundamental knowledge in the areas of lubricants and lubrication;

• Comprehend the significance of failures from the technical and economic aspects;

• Master the skills to evaluate the failure according to the established cause-consequence classifications;

• Comprehend the issue of establishing a diagnostic of machine condition and monitoring programme;

• Increase the availability and productivity of the equipment through a clearly defined technical strategy and to make competent decisions on it.

learning outcomes
Based on the mastered knowledge the student is qualified to:

• Conducts an analysis of the problems connected with maintenance and competently decides on the maintenance program in the tribotechnique area;

• Describes and distinguishes types of liquid, semi-liquid, gaseous and solid lubricants and their basic characteristics;

• Choose the appropriate lubricant and method of lubrication for the basic machine elements and mechanical systems;

• Selects and uses the modern methods for condition-diagnostic and condition-monitoring of the tribological systems;

• Make conclusions, based on monitoring results, about ways how to prevent the failure;

• Carry-out all the maintenance measures in tribotechnique domain and systematically introduce them into the working practice with the aim to reduce the losses due to friction and wear.

theoretical teaching
• Introductory lecture – The objectives and tasks of tribotechnique.

• Lubricants – role, type, classification and basic properties.

• Forms and types of lubrication; Hydrostatic, hydrodynamic, elastohydrodynamic and boundary lubrication.

• Lubrication systems (tasks and roles; procedures and classification; elements definition); Selection of lubricants and lubrication of the main machine elements and mechanical systems.

• Lubrication services organization and lubricants ecology.

• The role, objectives and techniques of failure analysis and condition-diagnostics in the construction and maintenance of mechanical systems (casual, permanent, partial, immediate and gradual failure); Failure analysis.

• Tribotechnique activities and sustainable development (maintenance methods, road map to excellence, performance benchmark);

• Basic methods of technical diagnostics (diagnostics based on vibration monitoring, diagnosis based on the monitoring of thermal conditions and diagnostics through wear products in the lubrication oil).

• Lubricants monitoring and the diagnostic methods for tribological components and systems condition.

practical teaching

• Classifications and specifications of lubricants; Methods for lubricants testing.

• Laboratory practice: "Experimental methods for evaluation of lubricants basic properties"; Measuring of: flash point and pour point; acid and total base number; foaming tendency; oxidation stability; ash, water and mechanical impurities contents; viscosity and viscosity index.

• Examples of failure analysis techniques (Fault tree analysis, Ishikawa diagram, Pareto analysis, FMEA, etc.) and their application to the specific tribological components failure case studies;

• Presentation of tribological components damages and failures of, and wear products (debris); Presentation of equipment for tribological components diagnostics.

• Project task: A survey of potential types of failures; analyze of the probability, causes and consequences of real and potentional failures of the components or systems; using some of the failure analysis techniques (fault tree, Ishikawa diagram, Pareto analysis, FMEA etc.).

prerequisite

No special requirements.

learning resources

1. --, Handouts for each lecture.

2. A. Rac, Lubricants and Machine Lubrications, Faculty of Mechanical Engineering, Belgrade, 2007, (in Serbian).

3. M. Babić, Lubricating Oil Monitoring, Faculty of Mechanical Engineering, Kragujevac, 2004 (in Serbian).

4. Various devices for measuring the basic characteristics of liquid lubricants and greases; Viscometer for liquid lubricants; Pressure grease viscometer.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 8
calculation tasks: 0
seminar works: 0
project design: 9
consultations: 13
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 3

check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 10
final exam: 30
requirements to take the exam (number of points): 35

references

B. Jeremić, Technology of Technical Systems Maintenance, ESKOD, Kragujevac, 1992, (in Serbian).
--, Handbook of Loss Prevention, Springer-Verlag, Berlin, 1978.
R.A. Collacott, Mechanical Fault Diagnosis, Chapman and Hall, London, 1977.
H.E. Boyer (Ed.), Metals Handbook – Failure Analysis and Prevention, American Society for Metals, Metals Park, 1975.
A.R. Lansdown, Lubrication – A Practical Guide to Lubricant Selection, Pergamon Press, Oxford, 1982.

Welding metallurgy

ID: MSc-0901
responsible/holder professor: Prokić-Cvetković M. Radica
teaching professor/s: Popović D. Olivera, Prokić-Cvetković M. Radica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
The aim of this course is for students to become competent in the areas of materials and welding and also to develop appropriate academic skills needed for the future profession. This course is designed to provide informations through theoretical lectures, computational classes, seminar papers and through welding workshop practice.

learning outcomes
Upon the successful completion of the course, the students are able to:

- Understand the distribution of temperature in the material during welding, and the influence of heat input on metal solidification
- Name all possible types of cracking (hot-, cold-, lamellar-, and reheat cracking) that may appear in the welding process, and to be able to differentiate between them
- Understand the metallurgical aspects of various steel classes (carbon-, low alloyed, high alloyed, stainless), and select the proper welding technique and appropriate welding consumables
- Understand the metallurgical aspects of weldability of different types of non-ferrous metals and alloys (Al and Al alloys; Cu and Cu alloys; Ni and Ni alloys; Ti, Zr, Mg and their alloys)
- Understand the metallurgical aspects of the weldability of heterogeneous metals
- Apply the concept of predicting crack appearance in the welded joint depending on the type of material and welding technology, in the goal to avoid the occurrence of damage and failure

theoretical teaching
Introduction. Physical basics of welding. Chemical reactions during welding. Welding thermal processes. Cracking phenomena in welded joints. Heat treatments of welded joints and CCT diagrams. Introduction to welding metallurgy of steels. The weldability of unalloyed and high strength steels. Welding of creep resistant steels and steels for cryogenic and low temperature services. Welding of stainless and heat resistant steels. Welding of nonferous materials.

practical teaching
Residual stresses and distortions of welds. Structural changes in welded joints. Application of CCT diagrams. Heat treatment of welded joints. The weldability of different grade steels - Carbon equivalent (CE), Cr and Ni equivalents. Welding discontinuities and defects. Testing of welded joints. Joining of dissimilar materials. Welding of nonferous materials: Al, Cu, Ni, Ti, Mg, Zr, Ta and their alloys. Welding of cast irons and steels. Processes of joining nonmetalic materials (plastics, ceramics and composites). Practice in welding workshop.

prerequisite
Passed exams in Engineering materials 1 and Engineering materials 2. Attended course - Welding processes.

learning resources

1. A Sedmak, V. Sijacki Zeravcic, A. Milosavljevic, V. Djordjevic, M. Vukicevic, Engineering materials, second part, Faculty of Mechanical Engineering, Belgrade, 2000.

2. V. Sijacki Zeravcic, A. Milosavljevic, A Sedmak, Manual for Engineering materials – Welding, Brazing and Casting, Faculty of Mechanical Engineering, Belgrade, 1996.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 12
laboratory exercises: 6
calculation tasks: 1
seminar works: 15
project design: 0
consultations: 6
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 20

references

B. Sabo at all, Weldability stainless steels, N. Sad, 1995.
i. Hrivmjak, Weldability steels, Gradjevinska knjiga, Belgrade, 1982.
S. Kou, Welding Metallurgy, second edition, 2003.

Welding technology

ID: MSc-1338
responsible/holder professor: Prokić-Cvetković M. Radica
teaching professor/s: Prokić-Cvetković M. Radica, Sedmak S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: engineering materials and welding, tribology, fuels and combustion

goals
Understanding the basic principles of welding technology as a prescribed course of action to be followed when making a weld. Introducing students to techniques of material selection, preparation, preheating, methods and control of welding and subsequent thermal treatment. Understanding and solving exercises in welding technology. Development of an independent paper by creation and presentation of selected seminar papers.

learning outcomes
By attending the course the students are mastering the basic knowledge of welding technology. Theoretical considerations and computational examples enable the student to master all the necessary principles of welding technology needed for the manufacture of welded joints. Introducing students to current modern standards and recommendations in this field.

theoretical teaching
Introduction to basic principles of welding technology. Defining the prior specification of welding technology (PSWT). Qualification of welding technology (QWT). Specification of welding technology (SWT) - analysis of the document defined by JUS EN 288-2 standard, containing information about the manufacturer, the basic material, process and welding position, joint preparation, notch and edges, welding technique, additional material, all welding parameters, preheating temperature and interlayer temperature. Heat treatment after welding. Welding sequence. Qualification of welders - analysis of EN 287-1 standard, which includes the principles on which the qualification testing of professional welders for welding steel by melting is based.

practical teaching
Auditory exercises with examples of welding technology problems. Solving exercises in specification of welding technology - examples include various types and thicknesses of the base metal, welding process and position. Solving exercises in qualification of welding technology - examples include various types and thicknesses of the base metal, welding process and position. The defense and presentation of selected seminar papers.

prerequisite
required: Mechanical Materials 1,2,3; Basic of Welding Process B (M)

learning resources
[1] Written lessons from lectures (handouts)
[2] Plavšić N., Šijački-Žeravčić V., Stamenić Z.: Tables of mechanical materials, profiles, sheets and wires, Faculty of Mechanical Engineering, Belgrade, 2004;
[3] Excerpts from the standard
[4] S. Sedmak et al., The Challenge od Materials and Weldments, SSIL, Belgrade, 2008.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 5
seminar works: 10
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 3
final exam: 3

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 15
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

FLUID MECHANICS

Computational Fluid Mechanics

ID: MSc-0941
responsible/holder professor: Ćoćić S. Aleksandar
teaching professor/s: Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: fluid mechanics

goals
Student should gain basic theoretical knowledge and principles of computational fluid dynamics (CFD), to be able to perform basic numerical calculations by using CFD methods, and to learn to use open-source CFD software OpenFOAM.

learning outcomes
Upon successful completion of the course, students will be able to:

- explain the general principles of numerical solution of governing equations for fluid flow
- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow
- explain and apply principles of numerical grid generation
- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)
- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in various domains
- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow

theoretical teaching
Basic ideas and principles in CFD. Analysis of various forms of fundamental equations of fluid motion. Types of partial differential equations (PDE). Boundary conditions for PDEs. Finite difference method. Approximation of PDEs by finite differences. Explicit and implicit methods of discretization. Stability of explicit and implicit methods. Methods for solving systems of linear algebraic equations. Finite volume method (FVM). Disretization of fundamental equations of fluid motion in FVM. Domain discretization - grid generation. Structured, block-structured and unstructured grid. Criteria for determination the grid quality. Numerical solution of Navier-Stokes equation. Basic principles of modelling and solution of turbulent flow. Basics of CFD based on finite element method.

practical teaching
GNU/Linux operating system. Work in terminal (shell) and BASH environment. Python programming language. Numerical solution of Coutte flow using finite difference method (FDM), with explicit and implicit methods of discretization. Implementation in Python code. Numerical solution of hyperbolic PDE by methods of characteristics - water hammer problem. Implementation in Python code. Advanced software for postprocessing - paraview. Numerical solution of two-dimensional Laplace equation using FDM. Implementation in Python code. Finite volume method (FVM). Numerical solution of steady diffusion and convection-diffusion problems by FVM. Methods of convective term discretization: upwind, central and hybrid scheme. Implementation in Python code. Structure and code of OpenFOAM. Mesh generation in OpenFOAM: blockMesh, snappyHexMesh and cfMesh. Solution of diffusion problems in various domains with OpenFOAM. Solution of incompressible viscous fluid flow with OpenFOAM.

prerequisite

Passed exams: Fluid Mechanics B and Numerical Methods, and Fluid Mechanics M (not obligatory, but it's will be easier to follow the lectures).

learning resources

-

number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 40
auditory exercises: 10
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 50
final exam: 40
requirements to take the exam (number of points): 0

references

Anderson J. Computation Fluid Dynamics, The Basics With Applications, McGraw Hill Series in Aeronautical and Aerospace Engineering
Versteeg H., Malalasekera, An Introduction to Computational Fluid Dynamics - The Finite Volume Method, Pearson Prentice Hall

Computational Fluid Mechanics

ID: MSc-0939
responsible/holder professor: Ćoćić S. Aleksandar
teaching professor/s: Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: fluid mechanics

goals
Student should gain basic theoretical knowledge and principles of computational fluid dynamics (CFD), to be able to perform basic numerical calculations by using CFD methods, and to learn to use open-source CFD software OpenFOAM

learning outcomes
Upon successful completion of the course, students will be able to:

- explain the general principles of numerical solution of governing equations for fluid flow
- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow
- explain and apply principles of numerical grid generation
- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)
- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in various domains
- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow

theoretical teaching
Basic ideas and principles in CFD. Analysis of various forms of fundamental equations of fluid motion. Types of partial differential equations (PDE). Boundary conditions for PDEs. Finite difference method. Approximation of PDEs by finite differences. Explicit and implicit methods of discretization. Stability of explicit and implicit methods. Methods for solving systems of linear algebraic equations. Finite volume method (FVM). Disretization of fundamental equations of fluid motion in FVM. Domain discretization - grid generation. Structured, block-structured and unstructured grid. Criteria for determination the grid quality. Numerical solution of Navier-Stokes equation. Basic principles of modelling and solution of turbulent flow. Basics of CFD based on finite element method.

practical teaching
GNU/Linux operating system. Work in terminal (shell) and BASH environment. Python programming language. Numerical solution of Coutte flow using finite difference method (FDM), with explicit and implicit methods of discretization. Implementation in Python code. Numerical solution of hyperbolic PDE by methods of characteristics - water hammer problem. Implementation in Python code. Advanced software for postprocessing - paraview. Numerical solution of two-dimensional Laplace equation using FDM. Implementation in Python code. Finite volume method (FVM). Numerical solution of steady diffusion and convection-diffusion problems by FVM. Methods of convective term discretization: upwind, central and hybrid scheme. Implementation in Python code. Structure and code of OpenFOAM. Mesh generation in OpenFOAM: blockMesh, snappyHexMesh and cfMesh. Solution of diffusion problems in various domains with OpenFOAM. Solution of incompressible viscous fluid flow with OpenFOAM.

prerequisite

Passed exams: Fluid Mechanics B and Numerical Methods, and Fluid Mechanics M (not obligatory, but it's will be easier to follow the lectures).

learning resources

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number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 40
auditory exercises: 10
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 50
final exam: 40
requirements to take the exam (number of points): 0

references

Anderson J. Computation Fluid Dynamics, The Basics With Applications, McGraw Hill Series in Aeronautical and Aerospace Engineering

Versteeg H., Malalasekera, An Introduction to Computational Fluid Dynamics - The Finite Volume Method, Pearson Prentice Hall

Fluid Mechanics 1

ID: MSc-0829
responsible/holder professor: Stevanović D. Nevena
teaching professor/s: Milićev S. Snežana, Stevanović D. Nevena
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: fluid mechanics

goals
Aims of the course is to introduce students to basic principles and laws in fluid mechanics. Deeper understanding of basic equations of fluid mechanics allows the student to successfully apply them in process of finding the solution to specific engineering problems, and also improves his scientific and practical development.

learning outcomes
Students are trained to:

- apply the basic equations of fluid mechanics ie. equations of continuity, momentum and energy to describe the one-dimensional compressible fluid flow, two-dimensional potential incompressible fluid flow and fluid flow in the boundary layer;

- calculate one-dimensional subsonic and supersonic compressible fluid flow, such as: isentropic flow, adiabatic and isothermal flow with friction, inviscid gas flow with heat transfer, shock wave as well as the gas flow through the convergent and Laval nozzle;

- determine the velocity and pressure field for potential incompressible fluid flow which enables them to calculate forces which act on the contour in inviscid fluid stream. Also, based on acquired knowledge, by applying complex potentials, they can form complex flows which enable obtaining the desired contour shape and force which act on it;

- solve the boundary layer equations for flow over a flat plate and calculate friction shear stress at the plate surface, and therefore the drag force.

- modeling the turbulent flow by using the theory of turbulent flow and turbulent stresses models.

theoretical teaching
Physical and mathematical models, principles and phenomena of fluid mechanics. Physical and mathematical foundations of fluid mechanics. Forces, the general state of stress and stress models in fluids. General equations in fluid mechanics. Laws of conservation. Conservation of mass, momentum and energy.

Dynamics of inviscid fluid. Two-dimensional potential flow of inviscid fluid. Application of hydrodynamic singularities and theory of analytical functions of complex variable. Basic and complex potential flows. Combined straight line flow and sink, doublet. Flow past a cylinder. Kutta-Joukowski`s low.

Dynamics of viscous flow. Navier-Stokes equation. Steady, laminar flow of Newtonian incompressible fluid. Exact analytical solutions of the Navier-Stokes equation. Hydrodynamic lubrication theory.

Turbulent flows of incompressible fluid. Reynolds equation. Turbulent stress models. Turbulent flow in a hydraulically smooth and hydraulically rough pipe.

Application of momentum equation: turbo-reactive jet engine, Euler`s equation for turbo-machines, Pelton turbines.

Boundary layer theory. Prandtl theory. Boundary layer over a flat plate. Application of integral methods to boundary layer calculation.

One-dimensional model of fluid flow. Basic equations of one-dimensional flow. One-dimensional flow of incompressible fluid. One-dimensional flow of compressible fluid. Mach number. Adiabatic and isothermal compressible flow with friction. Shock waves. Inviscid gas flow with heat exchange. Gas flow in the convergent, divergent and Laval nozzle.

practical teaching
One-dimensional viscous incompressible flow. Methods of calculation of complex pipe networks. Hydraulic jump. Cavitations in turbo-machines and pipes.

One-dimensional invisced and viscous compressible flow through pipes and jets. Adiabatic and isothermal compressible flow with friction. Shock waves.

Dimensional analysis and similarity theory. Drag and lift forces.

Two-dimensional ideal flow. Stream function, velocity potential. Applications of Cauchy-Riemman equations. Basic and complex potential flows. Joukovsky function.

Exact solutions of Navier-Stokes equations. Basic theory of hydrodynamic lubrication.

Turbulent flows modelling. Fully developed turbulent flow in hydraulically smooth and rough pipes.

Prandtl equations of boundary layer. Integral methods application to boundary layer calculation.

prerequisite
Passed exams in following subjects: Fluid Mechanics B.

learning resources
Books of professors from the department, laboratory equipment; printed and hand-written materials (handouts).

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 28
laboratory exercises: 2
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 45
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 20

references

Čantrak S., Hidrodinamika, Mašinski fakultet
Đorđević V., (2000): Dinamika jednodimenzijskih strujanja fluida, Mašinski fakultet, Beograd.
Crnojević C., (1998): Klasična i uljna hidraulika. Mašinski fakultet, Beograd.
S., Benišek M., Pavlović M., Marjanović P., Crnojević C.: Mehanika fluida, teorija i praksa, Mašinski fakultet, Beograd, 2005..

Fluid Mechanics M

ID: MSc-1290
responsible/holder professor: Ćoćić S. Aleksandar
teaching professor/s: Lečić R. Milan, Milićev S. Snežana, Stevanović D. Nevena, Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: fluid mechanics

goals
Main goal is to learn student general principles of fluid mechanics and how to apply them in solving practical engineering problems. In that sense proper understanding of general laws and equations is necessary. This will also enable student to develop further in other topics based on fluid mechanics.

learning outcomes
Student will gain knowledge on general principles in fluid mechanics and develop capabilities of analytical thinking. Firstly, knowledge on general laws and various forms of general equations (continuity, momentum and energy) and constitutive equations (rheology, Fourier law), and how and when the equations could be approximated. Upon successful completion of the course student should be able to: apply dimensional analysis and similarity theory and their application in fluid mechanics problems; apply the theory of potential flows; apply one-dimensional theory for solving engineering problems: incompressible and compressible flow in pipes and nozzles.

theoretical teaching
Physical and mathematical aspects in fluid mechanics. Forces, state of stress and rheology. General equations of fluid mechanics. Conservation laws: mass, momentum and energy. Dynamics of inviscid flow. Potential flow: stream function and velocity potential and Cauchy-Riemann equations. Basic flows: source, sink, doublet, vortex and their superposition. Application of complex analysis in studying potential flows. Forces on the body in potential flow stream. Conformal mapping, airfoils, Kutta-Joukovski condition. Viscous flows. Some exact solutions of Navier-Stokes equations in cases of laminar flow. Turbulent flows of incompressible fluid. Reynolds equations and modeling. Turbulent flows is channels and pipes. Boundary layer theory. Prandtl equations of boundary layer. One-dimensional flows. Form of general equations for one-dimensional flows. Water hammer. One-dimensional gas flows. Speed of sound. Shock wave. Adiabatic and isothermal flows with friction. Quasi one-dimensional flows in nozzles: convergent and convergent-divergent nozzle. Basics of computational fluid mechanics (CFD).

practical teaching
Application of integral form of general equations - control volume analysis. Exact solutions of Navier-Stokes equations. Dimensional analysis. Planar potential flows of incompressible fluid. Stream function, velocity potential. Application of complex analysis in solving problems of potential flows. Conformal mapping. Integral analysis of boundary layer. Numerical calculation of water hammer. One-dimensional flow of compressible fluid - gas dynamics. Isothermal and adiabatic gas flow in pipes. Shock wave. Quasi one-dimensional flows in nozzles.

prerequisite
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learning resources
Library, computer classrooms

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 60
requirements to take the exam (number of points): 15

references

Gas Dynamics

ID: MSc-1011
responsible/holder professor: Milićev S. Snežana
teaching professor/s: Milićev S. Snežana, Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: fluid mechanics

goals
The student should:

1. acquire basic theoretical knowledge in the field of gas dynamics;

2. be trained to perform basic engineering calculations of compressible flows;

3. become familiar with the basic procedures for experimental research in gas dynamics.

learning outcomes
Attendance and regular monitoring of the theoretical and practical training the student should master the basic knowledge in the field of gas dynamics. This will enable him, on the one hand, to solve specific engineering problems in the elementary problems of compressible flows, and, on the other hand, help him to better understand other courses based on this scientific area.

theoretical teaching
Basic concepts. Basic equations. Continuity, momentum and energy equation. The concept of entropy. Disturbances of the final intensity. The normal shock wave. Oblique shock waves. Interaction and reflection of shock waves. Prantdl-Mayer expansion.

Flow through the nozzle. Equations for isentropic flow with varying cross-section. Convergent and de Laval nozzle - regimes of flow in the nozzle.

Non-isentropic flow. The influence of friction in the flows of gas in the pipes. Adiabatic and isothermal flow with friction. Flow with heat transfer.Characteristics of sonic flow over a body. Critical Mach number. Boundary layer. Interaction of shock waves and boundary layer.

Experimental methods and devices. Methods for flow visualization. Various types of wind tunnels. Basic methods for measuring pressure and temperature. Anemometric methods.

practical teaching
Application of the basic equations of gas flow. Speed of sound. Critical and total values of physical quantities. Assessing the impact of compressibility.

Isentropic gas flow. Calculation of normal shock wave. Conditions for the formation of oblique shock wave. Calculation of oblique shock wave. Calculation of gas flow through a sequence of shock waves. Interaction of shock waves in the flow field. Prandtl-Mayer expansion. Non-linearized airfoil theory. Calculation of the forces exerted by the fluid on airfoil in super-sonic flow.

Calculation of flow through the nozzle. Flow through convergent nozzle. Flow through de Laval nozzle. Supersonic diffuser. Determining the value of reactive force.

Non-isentropic flows. Calculation of adiabatic flows of viscous gas. Calculation of isothermal flow of viscous gas. Calculation of inviscid flows with heat transfer.

Linearized airfoil theory.

prerequisite
Passed exam in course Fluid Mechanics B

learning resources
1.Handouts; 2. Snežana S. Milićev, Aleksandar S. Ćoćić, Tables for calculation of compressible flows, Faculty of Mechanical Engineering, 2017.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 50
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Handouts
Tables for calculation of compressible flows with theoretical handouts, Snežana S. Milićev, Aleksandar S. Ćoćić, Faculty of Mechanical Engineering, 2017.
Compressible Fluid Flow, M. A. Saad
Modern Compressible Flow, J. D. Anderson

Microfluidics and Nanofluidics

ID: MSc-0940
responsible/holder professor: Stevanović D. Nevena
teaching professor/s: Milićev S. Snežana, Stevanović D. Nevena
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: fluid mechanics

goals

The aim of this subject is getting academic knowledge about fluid dynamical processes in micro and nano flows and introducing with scientific methods for predicting, analyzing and studying gas and liquid flow in structures of micrometer and nanometer characteristic dimensions.

learning outcomes

Students are trained to:

-apply the basic equations of fluid mechanics ie. equations of continuity, momentum and energy to describe the compressible and incompressible fluid flow in micro and nano channels;
-determine the velocity and pressure field for isothermal compressible and incompressible fluid flow in micro and nano channels, pipes and bearings for continuuma boundary conditions;
- calculate the velocity and pressure field for isothermal compressible gas flow in micro channels, pipes and bearings for the slip flow regime;
- calculate the velocity, pressure and temperature field for non-isothermal compressible gas flow in micro channels, for the slip flow regime;
-calculate the pressure and velocity field for electroosmotic flow in micro and nano channels and pipes;
- applie the law of diffusion equation and obtained analytical solutions which enables determination the change of a substance concentration in the micro channel with no fluid stream, as well as in the fluid stream;
-determine the equilibrium height in the capillaries and the time required for its achievement, as well as the change in the liquids position with time in the capillary pump.

theoretical teaching

Theoretical lessons contains fundamental fluid mechanics equations applied on fluid flow modeling in the micro and nano structures, rarefaction effect, slip and temperature jump boundary conditions, the behavior, manipulation and control of fluids that are confined to structures of nano and micrometer characteristic dimensions, electric double layer and Debye length, electrokinetic effects such as electrophoresis and electroosmosis which are often present in the micro-and nanofluidics, basic diffusion equations and some exact analytical solutions for the substance concentration in the fluid, the ability to use the process of diffusion for mixing and separation in micro and nanosystems, capillary phenomena that are important for micro and nanosystems, micro-pumps.

practical teaching

Practical lessons contains: application of the basic fluid mechanics equations, exact solutions for modeling fluid flow in the micro and nano structures which include different effects as rarefaction, slip and temperature jump at the wall,calculation of electro-osmotic flow for different channel geometries taking into account the presence of the double layer and Debye-Huckel approximation for the distribution of charge density in the electric double layer , calculation of electro-osmotic pumps of various structures, calculation of the propagation of the substance due to diffusion and advection for different conditions, calculation of capillary motion of fluids and capillary pump.

prerequisite
Third semestar of Master study

learning resources
[1]Stevanović N., Fundamentals of microfluidics and nanofluidike, Faculty of Mechanical Engineering, University of Belgrade, 2014.

[2] Karniadakis G., Beskok A., Aluru N., Microflows and Nanoflows Fundamental and Simulations, Springer, 2005.

[3] Kirby, B., Micro and Nanoscale Transport in Microfluid Devices, Cambridge University Press, 2010.

[4] Dongqing L., Encyclopedia of Microfluidics and Nanofluidics, Springer, 2008. [5]Stevanović,N.,Fluid flows in microdevices, Faculty of Mechanical Engineering, Belgrede,2010.

number of hours: 75

active teaching (theoretical): 30
lectures: 25
elaboration and examples (revision): 5

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 20
seminar works: 5
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 40
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Kirby, B., Micro and Nanoscale Fluid Mechanics Transport in Microfluid Devices, Cambridge University Press, 2010.
Dongqing L., Encyclopedia of Microfluidics and Nanofluidics, Springer, 2008.
Bruus H., Theoretical Microfluidics, Oxford University Press, 2008.
Tabeling P., Introduction to Microfluidics, Oxford University Press, 2005.

Multiphase flow

ID: MSc-1382
responsible/holder professor: Lečić R. Milan
teaching professor/s: Lečić R. Milan, Radenković R. Darko, Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: fluid mechanics

goals

The main objective of the course is to master the knowledge, calculation models and appropriate practical skills that treat the problems of one-dimensional flows of mixtures of fluids and solids in pipes and ducts. In the field of flow of homogeneous and non-homogeneous machinists, important engineering problems are particularly studied, such as: fluidization, pneumatic transport, hydraulic transport, pneumo-hydraulic elevators and problems of particle separation from fluid.

learning outcomes

The student has knowledge of a special field of flow of mixtures of fluids and solids. He knows and knows that he uses: characteristic particle shapes, various forms of volume and mass concentration, physical properties of mixtures, deposition rate, critical fluid velocity, and characteristic current magnitudes of one-dimensional flows. The basic outcomes of the course are learning and mastering the calculation skills for different classes of fluid flow of mixtures of fluids and particulates, such as: application of appropriate calculation models that provide basic engineering current parameters: pressure, flow rate, flow rate and pressure drop in pipes and ducts at specific flows: in fluidized beds, hydraulic and pneumatic transport and pneumo-hydraulic lift. An important part of learning outcomes is learning about different modes of transport, selecting and calculating separators.

theoretical teaching

TRANSPORTATION OF MIXTURES. The concept and types of mixtures. Granulometry. Eulerian and Lagrangian approaches to studying the flow of mixtures. Particle acting forces. Resistance force and Stokes solution for spherical particle. Deposition rate: solitary particles, dilute mixtures and in non-Newtonian fluids. Porosity. Concentrations - volume and mass. Viscosity and density of mixtures. FLUIDIZATION. Fluidization application. Pressure drop in fluidized bed at incompressible fluid flow. Calculation of pressure change in isothermal compressible flow. The first and second critical fluidization velocities. PNEUMATIC TRANSPORT.Application, Advantages and Disadvantages, and Pneumatic Transport Systems. Horizontal pneumatic transport. Fluid lift. FLYING PNEUMATIC TRANSPORT. Isothermal compressible streams of the mixture. Critical Stream Speed. Changing the pipe diameter along the pipeline route. HYDRAULIC TRANSPORT. Suspension rheology. Laminar suspension flow. Hydraulic transport of inhomogeneous mixture in horizontal, vertical and oblique pipelines. Determination of pressure drop during hydraulic transport of mixtures. Application and calculation of pneumo-hydraulic lift. SEPARATORS.EJECTORS.

practical teaching

TRANSPORTATION OF MIXTURES. Particle shape. Form factor. Equivalent particle. The force of resistance. Resistance coefficient. Mass concentration measurement. FLUIDIZATION. The movement of a particle through a fluidized bed. Porosity of fluidized bed. PNEUMATIC TRANSPORT. Change in pressure in an incompressible and compressible fluidized bed as a function of supplementary resistance. FLYING PNEUMATIC TRANSPORT. Pneumatic transport systems. Vacuum cleaners. Dispensers. SEPARATION. Degree of separation. Selection criteria for separator type. Solid material separation chambers. Canvas and electrostatic filters. Cyclones. HYDRAULIC TRANSPORT.

Application, division, critical fluid velocity and viscosity of the homogeneous mixture. Hydraulic transport systems. EJECTORS. Application, ejector characteristics. Determination of optimal ejector parameters.

prerequisite

Regular class attendance, completed and defended lab work. It is desirable that the course of Fluid Mechanics M be heard and explained.

learning resources

Chair Book and Collection (in the library). Laboratory equipment and installations.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 26
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 55
requirements to take the exam (number of points): 10

references

Multiphase flow M

ID: MSc-1381
responsible/holder professor: Lečić R. Milan
teaching professor/s: Lečić R. Milan, Radenković R. Darko, Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: fluid mechanics

goals
In the field of multiphase flows, important engineering problems are particularly studied, such as: fluidization, pneumatic transport, hydraulic transport, pneumatic-hydraulic lifts, cavitation, evaporation, condensation and biphasic flows. skills that treat the problems of one-dimensional multiphase flows in pipes and ducts.

learning outcomes
The student has knowledge in the field of multiphase flows - mixtures of fluids and solids, or mixtures of different fluids. He knows and knows that he uses: characteristic particle shapes, various forms of volume and mass concentration, physical properties of mixtures, deposition rate, critical fluid velocity, and characteristic current magnitudes of one-dimensional flows. The basic outcomes of the course are to learn and master calculation skills for different classes of incompressible and compressible multiphase flows that take place without or with heat exchange, such as:

application of appropriate design models that provide basic engineering current parameters: pressure, flow rate, flow rate and pressure drop in pipes and ducts at specific flows: in fluidized beds, hydraulic and pneumatic transport, and pneumo-hydraulic lift. Using the knowledge gained, the student is able to dimension the pipeline system for transporting mixtures. An important part of learning outcomes is learning about different modes of transport, selecting and calculating separators.

theoretical teaching
The concept and types of mixtures and properties of mixtures.Basic equations for calculating the flow of mixtures. Laws of maintaining matter, quantities of motion and energy, equation of diffusion, equation of motion of particles. Eulerian and Lagrangian approaches to the study of multiphase flows. One-dimensional multiphase flow equations in pipes. Forces acting on gas bubble and solid particle, Stokes solution. Concentrations. MULTIPHASE FLUID AND SOLID PARTICLE FLOWS: Deposition velocities. Porosity.

Pressure drop in fluidized bed. Calculation of pressure change in isothermal compressible flow. The first and second critical fluidization velocities. PNEUMATIC TRANSPORT. Application, Advantages and Disadvantages, and Pneumatic Transport Systems. Horizontal pneumatic transport. Fluid lift. FLYING PNEUMATIC TRANSPORT. Isothermal compressible streams of the mixture. Critical Stream Speed. HYDRAULIC TRANSPORT. Suspension rheology. Laminar suspension flow. .Hydraulic transport of inhomogeneous mixture in horizontal, vertical and oblique pipelines. Application and calculation of pneumo-hydraulic lift. TWO-PHASE FLOW. Flow modes and maps in horizontal and vertical tubes. Determination of pressure drop. Lockart-Martineli method. Hydraulic characteristic of the mixture. Two-phase streams with separation surface. Cavitation, evaporation, condensation. Two-phase flows in heat exchange tubes. Numerical methods for multiphase flow calculation.

practical teaching
TRANSPORTATION OF MIXTURES. Particle shape. Form factor. Equivalent particle. The force of resistance. Resistance coefficient. Mass concentration measurement. FLUIDIZATION. The movement of a particle through a fluidized bed. Porosity of fluidized bed. PNEUMATIC TRANSPORT. Change in pressure in an incompressible and compressible fluidized bed as a function of supplementary

resistance. FLYING PNEUMATIC TRANSPORT. Pneumatic transport systems. Vacuum cleaners. Dispensers. SEPARATION. Degree of separation. Selection criteria for separator type. Solid material separation chambers. Canvas and electrostatic filters. Cyclones. HYDRAULIC TRANSPORT.

Application, division, critical fluid velocity and viscosity of the homogeneous mixture. Hydraulic transport systems. EJECTORS. Application, ejector characteristics. Determination of optimal ejector parameters.

prerequisite
Regular attendance. Preferably, the student has previously taken a course in Fluid Mechanics M.

learning resources
Chair Book and Collection (in the library). Laboratory equipment and installations.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 26
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 55
requirements to take the exam (number of points): 10

references

Pipeline fluid flow

ID: MSc-1291
responsible/holder professor: Ćoćić S. Aleksandar
teaching professor/s: Lečić R. Milan, Radenković R. Darko, Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: fluid mechanics

goals
The object of the course is to familiarize and study the important engineering problems related to pipeline fluid transport, and in particular to the methods of calculation of water, pipelines, oil pipelines, gas pipelines and steam pipelines. The goal is also to get acquainted with the problems of: water hammer, corrosion of pipelines and methods of techno-economic analysis of pipeline transport.

learning outcomes
As a result of the study of the subject is mastery of theoretical settings, physical laws, approximations and methods of calculation of one-dimensional flows of fluids through pipelines of special purpose, such as: water pipelines, oil pipelines, gas pipelines and steam pipelines. In the outcome of the course, they also gain practical knowledge that addresses technical problems: water hammer, pipeline corrosion, pipeline thermal dilatations, and how pipes are supported.

theoretical teaching
Physical properties of fluid, density and viscosity. Basic equations of one-dimensional flows in pipes. Electricity losses. Friction coefficient, exact and approximate formulas, empirical methods, time effects on friction coefficient change. WATERWAYS Calculation of branched and annular nets. Methods: Hardy-Cross, nodes method, linearization, and Newton-Raphson method. Flow rate measurements in pipelines. TRANSIENT PROCESSES IN HYDRO-SYSTEMS. Water hammer. 1D model of unsteady fluid flow. Speed of sound in elastic tubes, and in the presence of undissolved gases. Influence of pipeline geometry on sound speed. Methods of protection against hydro shock. Feature method. TRANSPORT OF HEATED LIQUIDS. Oil and gas pipelines. Fluid temperature change along pipelines. Determinination of pressure drop. OILS. Oil fields and composition. A rheological model. Isothermal stationary petroleum flow. Changing the temperature along the pipeline at different flow and thermal conditions. Determination of pressure drop of non-isothermal oil flow. TWO-PHASE FLOWS. Two-phase oil and gas flow modes. Becker's diagram. Determination of Lokart-Martinelli pressure drop-method. NATURAL GAS PIPELINES. A 1D steady-state gas flow model. Determination of friction coefficient in gas pipelines. Isothermal gas flow in inclined pipelines. Non-isothermal gas flow. Natur gas pipeline networks. Gas stations and substations.

practical teaching
MECHANICAL ENERGY LOSSES. The general form of the Darcy formula. Determination of the coefficient of friction. TRANSIENT PROCESSES IN HYDRO-SYSTEMS. Speed of sound in elastic tubes. The influence of how the pipe are supported on the speed of sound. Determination of speed of sound in a liquid in the presence of undissolved gases. OIL PIPELINES. Determination of pressure drop. NATURAL GAS PIPELINES. 1D model of isothermal and adiabatic friction flow and non-viscous flow with heat exchange.

prerequisite
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learning resources
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number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 25
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 0

references

GENERAL MACHINE DESIGN

Construction optimization

ID: MSc-1395
responsible/holder professor: Marinković B. Aleksandar
teaching professor/s: Rosić B. Božidar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: general machine design

goals
The main goal of this course for the student is to give the necessary knowledge of:

- numerical analysis and optimization,
- understanding general principles of design optimization,
- formulating the optimization problems and identifying critical elements,
- application of optimization methods on construction optimization.

learning outcomes
Upon completion of this course, students are able to successfully apply the theoretical and practical knowledge and are trained to:

- Formulate the optimization model of the mechanical system, identify relevant optimization variables, define the functional limitations and appropriate criteria for the multiobjective structural optimization task.
- Identify the domains of the practical application of relevant deterministic and stochastic variables, and to perform simulation and sensitivity analysis of a set of functional limitations due to the change of construction parameters,
- Select the best construction variant based on the established multiobjective optimization criteria,
- Recommend the process of decomposition of complex structural optimization models to less complex, and develop the appropriate application in MATLAB
- Analyze and apply one-dimensional and multi-dimensional numerical methods in the software package MATLAB,
- Apply and develop new optimization methods in order to determine the optimal set of parameters of the complex mechanical systems, individually or as part of an appropriate team.

theoretical teaching
1. Introduction to Modeling and Optimum Design Process. Optimum design problem formulation. A general mathematical model for optimization.
2. Graphical Optimization. Identification of feasible region. Use of MATLAB for graphical optimization.
3. Unconstrained Optimum Design Problems. Optimality conditions for functions of several variables.
4. Constrained Optimum Design Problems. Necessary conditions: equality constraints. Necessary conditions: inequality constraints - Karush-Kuhn-Tucker (KKT) conditions. Postoptimality analysis: physical meaning of Lagrange multipliers. Engineering design examples with MATLAB.

5. Nonlinear Programming. Problem formulation. Graphical solutions. Equality constrained problem. Inequality constrained optimization. Basic ideas and algorithms for step size determination.

6. Numerical methods - The One-dimensional Problem. Newton-Raphson method. Bisection method. Polynomial Approximation. Golden section method. Engineering Optimum Design examples with MATLAB.

7. Numerical Methods for Unconstrained Optimization. Numerical Methods - Nongradient methods. Powell's method. Numerical Methods-Gradient-Based Methods. Conjugate Gradient (Fletcher-Reeves) Method. Davidon-Fletcher- Powel (DFP) method.

8. Numerical Methods for Constrained optimization. Problem definition. Necessary conditions. Method of feasible directions. Gradient projection method. Exterior penalty function method. Optimum Design examples with MATLAB.

practical teaching
Consists of auditory and laboratory exercises.

Projects are main component of this course.

prerequisite
Knowledge of linear algebra and numerical mathematics. Computer programming in MATLAB.

Some knowledge of basic machine elements and mechanics.

learning resources
Computer Usage:

Students extensively use the computer and optimization toolbox using the MATLAB software package.

Handouts.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 21
calculation tasks: 0
seminar works: 7
project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Singiresu S. Rao "Engineering Optimization Theory and Practice" John Wiley and Sons, inc.
Jasbir S. Arora " Introduction to Optimum Design", Elsevier Academic Press
P. Venkataraman " Applied Optimization with Matlab Programming" John Wiley and Sons, inc
H. Eschenauer, J. Koski, A. Osyczka "Multicriteria Design Optimization", Springer-Verlag ;

Design and Construction M

ID: MSc-0373
responsible/holder professor: Mitrović M. Radivoje
teaching professor/s: Mitrović M. Radivoje, Mitrović M. Radivoje, Mitrović M. Radivoje, Mitrović M. Radivoje, Mišković Z. Žarko, Mišković Z. Žarko, Mišković Z. Žarko, Mišković Z. Žarko, Ristivojević R. Mileta, Ristivojević R. Mileta, Ristivojević R. Mileta, Ristivojević R. Mileta
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: general machine design

goals
Acquisition of basic knowledge of designing and constructing machinery elements and structures. Mastering the methods of construction and design process. Developing skills of teamwork and interconnecting knowledge and skills in various fields of Mechanical Engineering. Training for further study.

learning outcomes
After attended course, students gain knowledge about:

•Through the design stages they will be able to selects the optimum variant design from technological and economic point of view - Techno-economic analysis,
•Applying technical directives and regulations in the machine design and putting the product on the market,
•Evaluate the operational capacity of pressed joints,
•Resolves advanced problems with measuring chains
•Check capacity of thin and thick-walled pressure vessels from strength point of view,
•Make a selection of welded joints in terms of mutual position of the parts to be joined,
•To form and do the technical documentation of given mechanical construction.

theoretical teaching
Stages in the process of designing and constructing. Definition of executors for basic, partial and general functions. The formation of variant solutions and their evaluation - techno economic criteria. Selection of a compromise solution. The variant constructions. The product life cycle. Unification and typization. Measuring chains. The rules and regulations in the design process and constructing. Introduction to basic concepts and regulations related to construction processes in mechanical engineering. The necessity of compliance with regulations. Conformity Assessment. Harmonized standards. CE marking of products. Placing products on the market. Pressure vessels. Thick and thin walls pressure vessels. Operational stresses. Thermal strain. Critical stresses in static conditions. Selection of welded joints in terms of mutual position of parts to be joined. Types of edges and butt welds (shapes and dimensions) and their application domain. The behavior of structures in the area of low cycle fatigue. The behavior of structures in the area of high cycle fatigue. Design and construction of welded structures. Lightweight constructions. Technologibility in the process of constructing.

practical teaching
Variant construction solutions. Construction of typizated parts. Executors of elementary and partial functions. Forming and calculation of measuring chains. Application of rules and regulations in the machinery design process. Essay. Calculation problem training in the field of Pressure vessels. Example of constructing in the area of low fatigue load. Dimension calculation of elementary functions executors. Determination of service life. Calculation of light structures. The essay about dimension calculation of elementary and partial functions executors. Designing from fabrication and assembly point of view.

prerequisite
Passed all fundamental exams on B.Sc studies.

learning resources
Laboratory of Machine design, University of Balgrade, Faculty of Mechanical Engineering. Handouts, Presentations, Wireless Internet connection and access to the course Web presentation provided with usefull links.

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 4
project design: 0
consultations: 6
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 25
laboratory exercises: 0
calculation tasks: 30
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Ognjanović M.: Machine design, Faculty of Mechanical Engineering, Belgrade, 2000., in Serbian
Karl-Heinz Decker: Machinenelemente: Funktion, Gestaltung und Berechnung, Hanser Verlag, 2000.
Orlov P.: Fundamentals of Machine Design, MIR Publishers - Moscow, 1980.
S.Veriga: Machine elements 1, Faculty of Mechanical Engineering, Belgrade, 2000., in Serbian
Fundamentals of design - a collection of solved calculated problems, MFB, 1999, ZZD, bibl. FME, in sebian

Fixture Design

ID: MSc-1305
responsible/holder professor: Miloš V. Marko
teaching professor/s: Grbović M. Aleksandar, Kolarević M. Nenad, Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: general machine design

goals
Introduce the students with тxe design of specific elements and assemblies of complex machine systems.

learning outcomes
Upon successful completion of this course, students should be able to deal with the design of specific elements and assemblies of complex machine systems.

In addition to the methodology of calculation and preparation of technical documentation, students will have basic knowledge in the field of hydraulics, electronics and sensors as well as testing technology. They will be specially trained in the design of high-speed machines <24,000 rpm.

theoretical teaching
•Bearings

Types

Temperature during test (-40°C/140°C)

Misalignment compensation

Rotation speed

Axial/radial forces

Calculation for bearing selection

Lubrication

Grease vs. Oil

Seals

Cage types

Low friction

Fixed/loose/floating bearing principle

•Seals

Shaft seals

Rotating mechanical seal

radial shaft sealing ring

Housing seals

O – Ring seals

Materials

Calculations

Design principles of piston&rod

Fluid seals

•Couplings

Coupling types

Advantages/disadvantages

Compensation methods

Misalignment basics

Alignment of to shaft axis to each other

Rotary speed

shaft connections

Gear joints

Clamping devices

Key connection

Flange connection

Machine element calculations

•Technical drawings

International standards

Tolerance analysis basics

Root sum square method

design for manufacturing

design for assembly

•Design for manufacturing/design for assembly

Knowing production methods

Respect boundaries of production to be able to produce a designed part

Money/time/quality

Material selection

Frame/support parts

Rotationally symmetric parts

•FEA calculation basics

Stress calculation

Natural frequencies

•Hydraulic basics

Cooling/temper

Knowing dimensioning criteria

Open/closed loops

With oil or water glycol

Basic components

Basic calculation

Heat transition

Liquid friction

Drawing of piping & Instrumentation diagrams

Process measurement technology e.g. pressure, flow & temperature)

•Electric design

Design of switching devices

Define wiring of signal & power plugs

Obtain CE approval

Knowledge of components

•Sensors/measurement principles

Temperature, Infrared, Thermocouple

Torque measurement

Power analyzers

telemetry

•Tests

Endurance tests–time lapse

System tests of E-machines

•Design of high rpm machines <24.000 rpm

Bearing selection (Lubrication, Suitable types)

Coupling selection (Suitable types, Misalignments)

Balancing (Balancing methods & grades, Design principles)

Shaft seals (Suitable types, Rpm Limits)

Shaft connections

Machine dynamics calculations

Natural frequencies

practical teaching

Presentation of all machine elements that are the subject of design.

Visiting testing facilities.

prerequisite

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learning resources

1. Book-Tutorial:

Milos M., Grbovic A.: Software Tools in Design, University of Belgrade, Faculty of Mechanical Engineering 2017th.

2 Examples with the solutions and the necessary data for the calculations that are given in the book

3 Power-Point presentations, lectures available to students in the form of hand-out materials.

4 Moodle (Modular Object-Oriented Dynamic Learning Environment, open-source PHP web application for producing modular internet-based courses that support a modern social constructionist pedagogy).

5 Laboratory for Design in Mechanical Engineering.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 27
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 6
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 18
check and assessment of calculation tasks: 8
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 10
calculation tasks: 30
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 60

references

Hybrid Technical Systems

ID: MSc-0966
responsible/holder professor: Miloš V. Marko
teaching professor/s: Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: general machine design

goals
Acquisition of general and basic knowledge of hybrid technical systems (HTS) as the most complex form of the TS, introduction to the structure and terms of HTS as a whole, the basic principles of the system components and the basic approaches to modeling and simulation.

To qualify students to understand the complexity of the procedures and systems integration through precise and detailed general methodology.

Developing skills of teamwork and networking skills in various fields.

Training for further study.

learning outcomes
Students will gain knowledge of some methods in engineering design, which will enable them to plan and implement complex processes of modeling, simulation and integration of hybrid technical systems (HTS).

The knowledge gained will be used in engineering practice to select the basic elements of various technical systems and linking design methods.

Being trained to be responsible teamwork.

theoretical teaching
Hybrid technical and technological systems: clarification and definition of the basic concepts, HT systems: fundamentals of design and development of HT systems, structures and basic elements; modularization and hierarchization.

Integration: functional, spatial, methods of designing and connecting various technical units; role of information technology, mechanical components and assemblies, electrical components and circuits, electronic components and sensors; Microcontrollers and Programmable Logic Controllers (PLC), Hydraulic components and assemblies; Pneumatic components and assemblies; Executive elements, Control, modeling and simulation of HT systems: computation and defining the behavior of the system as a whole and the interaction between the individual components, computer models and simulation systems; production processes as HT system: computer integrated manufacturing, product development process, automation; realization of various HT systems.

Implementation of 3D technology in verification of the elements HTS.

practical teaching
Exercises include presentation software packages and design packages for simulation and analysis. Also, an example (modeling and simulation) of relatively complex actuator systems (electro-mechanical actuator) as a representative of HT systems will be presented. Upon completion of the calculation and simulation, practical work with actuator: measurement of certain parameters and presentation of contol; Three essays: HT system as a whole; calculation and simulation EMA, HA or PA; modeling HT systems.

Verification of mechanical assemblies using the 3D printing.

prerequisite
None

learning resources
Moodle (Modular Object-Oriented Dynamic Learning Environment, open-source PHP web application for producing modular internet-based courses that support a modern social constructionist pedagogy).

Lectures, power point presentations, room equipped with computers & software for design and simulations, Laboratory for HTS, 3D printer, handouts.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 27
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 12
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 18
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 13
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 45
project design: 0
final exam: 30
requirements to take the exam (number of points): 45

references
M. Milos: Hybrid Technical Systems – professor's handouts - Faculty of Mechanical Engineering, 2014.
M.Ognjanovic: Innovative Development of Technical Systems - Faculty of Mechanical Engineering, 2014.
N. Avgoustinov: Modelling in Mechanical Engineering and Mechatronics – Springer, 2007
W. Bolton: Mechatronics-Electronic Control Systems in Mechanical and Electrical Engineering – Pearson, 2012.
B. Wilamowski, D. irwin: Control and Mechatronics – CRC Press, 2012.

Innovative Design of Technical Systems

ID: MSc-1302
responsible/holder professor: Kolarević M. Nenad
teaching professor/s: Kolarević M. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: general machine design

goals
Introduce the students with the role and importance of innovative development of technical systems for the development of economics and technology at the global level until to small enterprises and individuals. Review the levels of innovation and market implementation procedure. Introduce students to the process of searching for ideas and solutions. The aesthetics or ecological properties or the transformation of biological principles into technical solutions may also be incentives and challenges. Introducing into the procedure of synthesis (creation) of a fundamentally new technical system, from the idea to the project that is the basis for its production, exploitation and recycling, is another goal. The overriding goal is to develop creative skills for engineering design.

learning outcomes
Upon successful completion of this course, students should be able to:

• Abstract thinking in the innovative creation (design) of a technical system.
• Manage the process of searching for ideas and design solutions.
• Create a conceptual structure (new operating principle) of a technical system based on the developed function structure.
• Raise the level of properties of technical systems in functional, aesthetic, ecological, market and other environmental conditions.
• Develop innovative technical solutions based on the transformation of biological systems, software and mental functions.

theoretical teaching
1. Meaning, role and importance of technical innovation
2. Procedure and models for innovative development of technical systems.
3. Transformation of function into conception and conception into structure.
4. Robust and axiomatic design of technical systems.
5. Property based design of TS. Partial approach in the development of TS - DfX approach
6. Theory of TS abstraction as the basis of innovation.
7. Methods of searching for innovative ideas and solutions.
8. Biological systems as a basis for technical innovation.
9. Development of aesthetic properties of innovative technical systems.
10. Effects of eco-friendly and ergonomic TS design and innovation.

practical teaching
In the course of semester the students working out seminar work which that allows them to understand the purport of the technical system functions. The starting point is existing design solution and the inverse procedure application leads the students to the abstract structure of the functions which is the basis for the development of innovative i.e. to the new design solutions. Auditory exercises also contains analysis and discussions of issues and practical examples covered by theoretical classes with the aim to introduce students to the phenomena that need to process in their seminar works and to prepare for the tests.

prerequisite
Defined by the curriculum of the study program / module

learning resources
1. Book-Tutorial:
Ognjanović M: Innovative development of technical systems (Chapter 2: The innovative design of technical systems) - University of Belgrade, Faculty of Mechanical Engineering 2014th.
2 Examples with the solutions and the necessary data for the calculations are given in the book referred to in the point 1.
3 Power-Point presentations, lectures available to students in the form of hand-out materials.
4 Laboratory for Design in Mechanical Engineering.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 10
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Ognjanovic M.: Innovative Development of Technical Systems (in Serbian), -University of Belgrade, Faculty of Mechanical Engineering, 2014.
Pahl G., Beitz W.: Engineering Design - A systematic approach, - Springer Verlag
Hubka V., Eder E.: Theory of Technical Systems, - Springer - Verlag
Hubka V., Eder E.: Design Science, - Springer - Verlag
Haufe T: DESIGN, - DuMont Buchverlag

Reliability of structures

ID: MSc-1396
responsible/holder professor: Lazović Kapor M. Tatjana
teaching professor/s: Ristivojević R. Mileta
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: general machine design

goals

Acquisition of basic knowledge about the reliability of mechanical components and structures. Mastering the methods of determining the reliability of simple and complex systems. Developing skills of teamwork and networking knowledge and skills in various fields. Training for further study. Consideration of the importance of failure from the technical and economic point of view, mastering the skills to assess the failure assessment, based on the cause-events established classifications.

learning outcomes

After the attended course, students gain knowledge about:

1. Explain the basic indicators of reliability,
2. Apply approximate procedures for determining the basic indicators of reliability of machine parts and structures,
3. Apply analytical procedures for the determination of the basic indicators of reliability of machine parts and structures,
4. Determine the parameters of the basic distribution on the basis of probability,
5. To analyze the influence of the distribution of operating and critical stress on the safety and reliability of machine parts and structures,
6. Determine the reliability of complex systems with series, parallel and combined connection of elements,
7. Construct machine parts and assemblies on the basis of reliability.

theoretical teaching

The importance of reliability in the design and construction process of mechanical structures. The definition of reliability. Key indicators of reliability. Estimated and theoretical reliability, confidence level. Reliability of elementary and partial function executor for various failure intensity functions: constant function, linear and exponential growing function. Distribution of work and critical stress. Comparative analysis of the construction based on the degree of reliability and safety factor when the values of average operating stress and critical stress change in proportion, and the standard deviation does not change even when the mean values of operational and the critical stress does not change, with a change of standard deviation. The methodology of sizing of elements and joints based on the mechanical design reliability required. Reliability of mechanical structures for different connections (structure) elements: serial, parallel and combined. Statistical analysis of complex tolerance (tolerance of measuring chains). Optimizing the reliability cost. Correlation between reliability and safety factor for different relations of standard deviation and average values of operating and critical stress.

practical teaching

Determination of the basic indicators of reliability by the approximate method. Determining the reliability on the basis of analytic functions of reliability. Distribution of work and critical stress. Dimension calculation of machine elements on the basis of reliability. Reliability structure with the serial, parallel and combined connection of elements. Statistical analyses of complex tolerances. Reliability and safety factor correlation.

prerequisite
No condition.

learning resources
Laboratory of Machine design, University of Belgrade, Faculty of Mechanical Engineering. Handouts, Presentations, Wireless Internet connection and access to the course Web presentation provided with useful links.

number of hours: 75

active teaching (theoretical): 30
lectures: 30
elaboration and examples (revision): 0

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 0
calculation tasks: 6
seminar works: 3
project design: 0
consultations: 6
discussion and workshop: 1
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 0
final exam: 50
requirements to take the exam (number of points): 26

references
Nikola Vujanović, Teorija pouzdanosti tehničkih sistema, Vojnoizdavački i novinski centar, Beograd, 1990.
Vladimir Zeljković, Stevan Maksimović, Proračun pouzdanosti mehaničkih elemenata i konstrukcija, Grafokomerc, Beograd, 1998.
Gradimir Ivanović, Pouzdanost tehničkih sistema, Beograd, 2011
Milosav Ognjanović, Razvoj i dizajn mašina, Beograd, 2000
Handout

Skill Praxis M - DUM

ID: MSc-1228
responsible/holder professor: Miloš V. Marko
teaching professor/s: Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: general machine design

goals
Practical experience and stay student in an environment where will realize his professional career. Identifying the basic functions of the business system in the field of product development, production and use as well as the role and tasks of mechanical engineers in such a business system.

learning outcomes
After completion of the Professional training - M - DUM, students should gain insight into the practical aspects of the innovative and creative work of engineers in the next.

- In recognition of the basic functions of the business system in the field of TS development, production and use of TS as well as the role and tasks of engineers in such a business system.

- The manner of organization and functioning of the environment in which it will apply the acquired knowledge in their future professional career or entrepreneurial work.

- The models of communication and flows in the development and implementation of product and market realization.

- In recognition of the basic processes in engineering design, manufacture and maintenance of TS.

theoretical teaching
Introduction, aim, content activity.

practical teaching
Practical work means work in organizations where they perform various activities in connection with mechanical engineering. The choice of thematic units and commercial and research organizations carried out in consultation with the subject teacher. In principle, the student can carry out the practice in manufacturing organizations, project and consulting organizations, organizations dealing with maintenance of mechanical equipment, public utility companies and one of the laboratories at the Faculty of Mechanical Engineering. The practice may also be made abroad. During the practice students have to keep a diary in which to enter a description of the tasks they perform, the conclusions and observations. After completed practice must make a report that will defend in front of the subject teacher. The report shall be submitted in the form of a seminar paper.

prerequisite
-

learning resources
Organizations that includes life-cycle product development, production, use.

-Organizations engaged in product development.

-Industrial Companies whose business is making products in mechanical engineering.

-Industrial Companies whose business is based on the use of mechanical systems.

-The companies whose activity is distribution and maintenance of machines and components.

number of hours: 90

active teaching (theoretical): 2
lectures: 2
elaboration and examples (revision): 0

active teaching (practical): 78
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
consultations: 0
discussion and workshop: 0
research: 48

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 50
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references

Software Tools in Design in Mechanical Engineering

ID: MSc-0963
responsible/holder professor: Miloš V. Marko
teaching professor/s: Grbović M. Aleksandar, Kolarević M. Nenad, Miloš V. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: general machine design

goals
The main objective of this course is to achieve basic competence in the process of generating of technical systems and innovation, as well as introduction of basic academic knowledge of the capabilities and use of specialized software applied in three stages in the product development (design, elaboration of technological processes and the production).

learning outcomes
Students will acquire knowledge, tools and practical skills in the application of specialized software for the design and construction (engineering design) as well as programs that enable communication between various software for different purposes.

theoretical teaching
Basic definitions provided in mechanical engineering design. The notion of a technical system. The concept of technical innovation. Creation of technical systems and innovation.

Basic capabilities of CATIA software (3D models and from them derived two-dimensional drawings and plans, linking them with additional modules for the kinematic calculations, FEM calculations and NC-programming).

Processing of 3D geometry imported into CATIA software from 3D scanners; translating from .stl format to .igs or .stp records suitable for improving the geometry and FEM analysis.

Basic design methods in the program SolidWorks.

Interface programs that enable communication between the software for different purposes, and their interconnection.

Linking programs CATIA and SolidWorks programs for the implementation of the finite element method Ansys and Abaqus; process optimization design.

Methods of computer analysis and optimization of the product; parametric optimization of three-dimensional structural elements (Goal Driven Optimization in Ansys) and structural optimization (using Altair HyperShape).

DELMIA software package; virtual planning, defining, monitoring and controlling production processes necessary to transform a computer model to a real mechanical products.

practical teaching
Examples of the application of software tools in the processes of the designing products used in the motor vehicle industry, shipbuilding, mechanical engineering, machinery, aviation,...

Practical exercise on a 3D printer.

Demonstration exercise of the NC machine.

prerequisite
None

learning resources

Moodle (Modular Object-Oriented Dynamic Learning Environment, open-source PHP web application for producing modular internet-based courses that support a modern social constructionist pedagogy).

Lectures, power point presentations, romm equipped with computers & software for design and simulations, 3D printer (Laboratory for Hybrid Technical Systems), NC machine, handouts.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 27
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 12
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 18
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 13
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 45
project design: 0
final exam: 30
requirements to take the exam (number of points): 45

references

M. Milos, A. Grbovic: Software Tools in Design in Mechanical Engineering – professor's handouts - Faculty of Mechanical Engineering, 2014.
M. Ognjanovic: Innovative Development of Technical Systems - Faculty of Mechanical Engineering, 2014.
User's Manual(s)

Structure Modelling with Calculation

ID: MSc-1098
responsible/holder professor: Marinković B. Aleksandar
teaching professor/s: Kolarević M. Nenad, Marinković B. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: general machine design

goals
The aim is to introduce students to the understanding of space and geometric forms in 3D environment. Intention is also understanding the topology types of machine parts, such as methodology of forming a 3D model as a starting point for the development of forms of machine parts and assemblies.

Machine components shape and dimensions determination used to be conducted based on previous knowledge and overpowered skills from Machine elements 1 and 2 courses. Learning and exercising of procedures and tools developed for manipulating forms and dimensions with parameter changes. Aim od this modification is to get an optimum shape that allow us to achieve optimal solutions in machine design modeling.

learning outcomes
Starting from basics in Machine elements, student used to define shape design of machine components concerning their dimensions and function. Taking into account other design criteria, student has skills to manage corresponding shapes of common machine components using CATIA software. It is completely trained to parametrically vary the shape and form parts, to optimize the form and combine them to compose the assembly. Student has acquired knowledge that the application of CATIA tool optimizes the shape and adjust the properties of this form. The student is also familiar with basics of using modules for simulation and structural analysis.

theoretical teaching
Introduction, on the course and shape modeling (concept model, role models, use of models). Modeling tools, for software and their characteristics. Principles and method of modeling the form. Surface modeling, surface models. Modeling geometric body (Boolean operations). Additional tools for modeling shapes in CATIA V5.

Forming of machine components shape based on dimensions and their functional determination. Overview of calculation and shape design for shafts, sliding bearings, thread couples, springs and other important components of machine.

Parametric modeling, role and importance of parametric approach. Principles of modeling components. Modeling shape and production of technical documentation. Advanced tools and commands in the modeling using CATIA V5. Further application forms and components modeled in the simulation and analysis.

practical teaching
Introductory class. Training Concept with calculations and projects, Importance of dimensions calculation and function of machine components aime to define their proper shape. Calculation methods and determination of shafts and axles dimensions and shapes, Calculation methods in determination sliding bearing, thread pairs, springs and other important machine components dimensions and shapes. Application of calculation results in shape design of machine components using CATIA V5 software tool.

The concept of using CATIA V5 software. The content of the program and the general settings of CATIA V5. Drawing projection and profile (Sketch). Body Modeling (Part Design), the basic principles and advanced commands. Shape modeling (Shape Design), it advantages and disadvantages. Defining relationships between the parameters of the modeled shape. Fundamentals of modeling assemblies (Assembly Design). Modeling circuits of varying complexity (Assembly Design). Obtaining drawings and preparation of technical documentation (drafting). Advanced tools and commands, special modules in CATIA V5. Introduction to analysis and simulation of components and assemblies.

prerequisite
Required: Attended and passed Engineering Graphics, Machine Elements 1 and Machine Elements 2

Preferred: Attended and passed Basics of Machine Design

learning resources
book "Shape Modeling" A.Marinković, M.Stanković, Mechanical Engineering Faculty 2011.;
other literature for CATIA V5 software;
hand-outs of lessons;
equipment available in room 455, 3D printer and computers;
CAD working station, CAD software tool CATIA V5.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 6
> laboratory exercises: 0
> calculation tasks: 4
> seminar works: 0
> project design: 10
> consultations: 4
> discussion and workshop: 4
> research: 2
>
> **knowledge checks:** 15
> check and assessment of calculation tasks: 4
> check and assessment of lab reports: 0
> check and assessment of seminar works: 0
> check and assessment of projects: 5
> colloquium, with assessment: 1
> test, with assessment: 1
> final exam: 4

assessment of knowledge (maximum number of points - 100)

> feedback during course study: 0
> test/colloquium: 30
> laboratory exercises: 0
> calculation tasks: 20
> seminar works: 0
> project design: 20
> final exam: 30
> requirements to take the exam (number of points): 35

references
CATIA V5 documentation and tutorials for Shape Design and Structural Design modules
Ognjanovic M.: Innovative Development of Technical Systems (in Serbian), -University of Belgrade, Faculty of Mechanical Engineering, 2014.

Technical regulations and standards

ID: MSc-0141
responsible/holder professor: Mitrović M. Radivoje
teaching professor/s: Mitrović M. Radivoje, Mišković Z. Žarko, Stamenić V. Zoran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: general machine design

goals
Acquiring basic knowledge in the field of technical regulations and standards. Fully understanding the mutual correlation between international and national technical regulations. Full training for the project documentation making in terms of respect for the essential requirements relevant to technical regulations and standards.

learning outcomes
After attended course, students gain knowledge about:

- the content, significance and types of technical regulations and standards,
- technical legislation of EU directives,
- conformity assessment procedures, notified bodies,
- CE marking, market surveillance,
- machinery safety,
- Risk assessment and national legislation on safety and health at work.

theoretical teaching
Theoretical Studies: The role, importance and types of technical regulations in mechanical engineering. The place and role in the process of technical regulations and machinery design. Standardization. Application scope. Lows about standardization. Low of Accreditation. Low of Metrology. Lows of Technical Directives. Directives and other regulatory legislation documents. EU technical legislation. EU directives. The meaning of new and global approach. Scope of application of the New Approach Directives. Products and goods covered by directives. Compatibility to the Directives. Standard procedure for conformity assessment. Modules. Quality standards application. Notified bodies. Principles of Accreditation. The process of certification. Notified bodies and subcontracting. Coordination and cooperation of notified bodies. CE marking. The principles of the CE markings. Products which is marked with CE. Market surveillance. Principles of market surveillance. Machinery safety. Reliability. Hazard. Risk. Functions of machinery safety. Safety protection. Manual Instruction. Strategy for selection of safety measures. Risk assessment. The evaluation of risk. Law on Safety and Health at work.

practical teaching
Examples of application and use of various types of technical regulations and standards in the construction and design process. Examples of formation and complete technical documentation for obtaining the CE mark for the product. Examples of forming and completing the documentation for the accreditation of laboratories for product testing. Examples and conformity assessment of products. Examples of designing technical solutions for machinery safety and protection. Example of making manual instructions for machinery, equipment or installations. Examples of risk assessment for machinery and mechanical systems. Examples of completing a documentation for the risk assessment. During course, students will visit the following institutions:

- Certified Laboratory for Machinery Elements and System Testing - LIMES, University of Belgrade, Faculty of Mechanical Engineering;

- Directorate of Measures and Precious Metals (DMDM)of Republic of Serbia;

- The Intellectual Property Office of Republic of Serbia;

- Institute for Standardization of Serbia;

- Notified Body of Vinča Institute.

prerequisite
There are no special requirements for attending the course.

learning resources
- Teaching material: Instructions for the application of directives based on new approach and global approach - Danish Technological Institute (translated version) 2006, EU Directive, EU Standards, Standards of Republic of Serbia, the Law on Standardization, the Law on Accreditation Act, the Law on Metrology, Lawc on technical regulations. Required additional materials (handouts, Directives Of Republic of Serbia, etc..) are given at the web site or as a hard copy. Large-scale electronic materials can be made available to students in direct contact.

- Computer equipped classroom;

- Access to Internet;

- Laboratory for General Machine Design, University of Belgrade, Faculty of Mechanical Engineering;

- Certified Laboratory for Machinery Elements and System Testing - LIMES, University of Belgrade, Faculty of Mechanical Engineering;

- Certified Laboratory for Vehicle Testing - CIAH, University of Belgrade, Faculty of Mechanical Engineering;

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 2
project design: 0
consultations: 5
discussion and workshop: 8
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 10
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 25
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Fundaments of Technical Regulatives, University of Belgrade - Faculty of Mechanical Engineering, Belgrade, 2015.
Actual Directives and regulation books of Reublic of Serbia
EU Directives (MD, LVD, EMC, HACCP, ATEX,...)
Technical regulations and standards, textbook in preparation

HYDROPOWER ENGINEERING

Fans and turbocompressors

ID: MSc-0809
responsible/holder professor: Čantrak S. Đorđe
teaching professor/s: Janković Z. Novica, Čantrak S. Đorđe
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: hydropower engineering

goals
Mastering knowledge of engineering applications of fans and turbocompressors as machines for raising of fluid energy. Capacity to work in practice on energy installations, as well as design of installations that include a fan or turbocompressor as built-in element with its function.

learning outcomes
Upon successful completion of this course, students should be able to:

1. identify and describe the various types and constructions of the fans and turbocompressors, the principles of their work, as well as the standard way of their installation,

2. determine the duty points of the ventilation system and fan,

3. select the appropriate fan and the most energy efficient way of its regulation,

4. determine the duty point of the fan by using the dimensionless parameters (characteristic coefficients),

5. calculate the fan characteristics when working with other fluid density,

6. calculate the thermodynamic and energy parameters of the turbocompressor,

7. design and develop (with the help of CNC and 3D printers) the 3D model of multistage axial compressor, with special emphasis on the impeller blades and guide vanes.

theoretical teaching
Task and constructions of fans. Examples of application. Similarity theory, dimensionless parameters and fans classification. The calculation of basic dimensions of the fan – type, impeller diameter, impeller outlet width, spiral casing. Matching and regulation of fans. Testings of fans. Specifics of fan and fan systems. In built characteristics of fans. Axial fans without stay vanes - a characteristic of the fan, its matching. Turbulent swirl flow phenomenon in pipes and jets. Air curtains, reversible fans, fans for fire conditions, ceiling and roof fans, fans in cooling systems. Fan selection. Fans in building energy certification. Building air leakage test ("blower door" test). Noise levels of a fan and fan installation. Thermal machines classification. Task and constructions of turbocompressors. Energy balance. Thermodynamic basis. Efficiency. Uncooled and cooled turbocompressors. The exchange of energy in the axial grid. Multistage compressors. Typical performance curves of axial turbocompressors and behavior in work (choke and surge limits). Determination of optimal characteristic coefficients of centrifugal compressors. Performance curves of centrifugal compressors and their behavior at work.

practical teaching
1. Auditory exercises:

Calculation examples of lectured material: Matching and regulation of fans. Fan selection. Thermodynamic analysis. Efficiency determination for cooled and uncooled turbocompressors. Multistage turbocompressors.

2. Project design:

2.1. Presentation of the manual for multistage axial compressor design: from calculation of basic dimensions to 3D model.

2.2. Introduction to the application of the existing softwares for turbocompressor design.

3. Laboratory exercises:

3.1. Demonstration:

Laboratory for hydraulic machines - constructions of fans and turbocompressors and description.

3.2. Active laboratory exercises:

1.Testing of the fan performance curves.

2.Determination of sound power levels of noise sources (fan) using sound pressure.

3.Fan electrical motors and regulators wiring and starting the machines.

prerequisite
Completed courses: Fluid Mechanics B and Thermodynamics B.

learning resources
1. Textbooks listed in the references and list of literature provided for students.

2. Lectures and exercises handouts.

3. Manual for multistage axial turbocompressor design.

4. Laboratory for hydraulic machines - fans and turbocompressors, installations, measuring equipment.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 25
auditory exercises: 12
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 20
check and assessment of calculation tasks: 3
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 50
laboratory exercises: 5
calculation tasks: 0

seminar works: 0
project design: 15
final exam: 30
requirements to take the exam (number of points): 21

references

Genić S., Stamenić M., Živković B., Čantrak Đ., Nikolić A., Brdarević Lj. (2017): Manual for energy managers' training in the industry energetics, Fac. of Mech. Eng., University of Belgrade, Belgrade
Protić Z., Nedeljković M. (2010): Pumps and Fans. Problems, Solutions, Theory, 6th ed., Faculty of Mechanical Engineering University of Belgrade, Belgrade. (in Serbian)
Obradović N. (1974): Turbocompressors, Faculty of Mechanical Engineering University of Belgrade, Belgrade. (in Serbian)
Ilić D. B., Čantrak Đ. S. (2017): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
Bommes L., Fricke J., Grundmann R. (Eds.) (2002): Ventilatoren, 2. Aufl., Vulkan-Verlag, Essen (in German).

Hydraulic turbines

ID: MSc-0808
responsible/holder professor: Božić O. Ivan
teaching professor/s: Božić O. Ivan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: hydropower engineering

goals
Achieving academic competence in the fields of hydraulic turbines and hydropower.

Mastering theoretical knowledge of flow process through the turbines and energy transformation therein (fluid and mechanical system interaction).

Obtaining practical knowledge in optimal energy and cavitation performances calculation of hydraulic turbines.

Having the relevant know-how for the turbine industry, design companies and power plants.

learning outcomes
On successful completion of this course the students will be able to:

- recognize different types and constructions of hydraulic turbines,

- describe the principles of operation, explain and analyze fluid flow in various hydraulic turbines,

- define, calculate and analyze the specific geometry, energy and cavitation parameters of hydraulic turbines,

- construct the essential components and explain their roles from the point of the optimal energy transfer process in various hydraulic turbines,

- design and choose the optimal type and geometry of hydraulic turbines flow passages with the aim of high efficiency operation of hydropower plants,

- define, analyze and apply universal characteristics and operational hill charts for hydraulic turbines, and their scale up (model to prototype).

theoretical teaching
Principles of operation, application and classification of hydraulic turbines. Water resource and its potential. Basic and main parameters of the turbine. Theoretical basis of flow through the turbine and energy transforming by fluid and mechanical systems interaction. Flow calculation in the turbine runner. Cavitation in turbines, cavitation coefficient and determination of the suction height. Hydraulic turbines similarity laws. Unit and specific parameters of the turbines. Energy and cavitation model parameters scale-up to a turbine prototype. Regulation of turbine discharge. Turbine characteristics: linear and universal. Operation (hill-chart) characteristics of the turbines. Turbine flow passages. Contemporary turbine constructions. Runaway characteristics. Transients in the turbines.

practical teaching
Auditory exercises and calculation examples:

Hydropower plants operation fundamentals. Historical development, classification, properties and application of turbines. Determination of basic and main parameters (gross and net head, discharge, power, efficiency, hydraulic and mechanical power losses, rotational speed). Application of Euler's equations for the turbine. Determination of velocity triangles, relation between specific energies of turbine unit and runner, degree of reaction and hydraulic axial force. Determination of unit and specific turbine parameters. Scale-up of turbine model hydraulic efficiency characteristics and cavitation coefficient to a turbine prototype. Determination of suction height. Determination of universal and operation (hillchart) turbine characteristics. Cam curve determination. Construction of Pelton, Francis, Kaplan and bulb turbine. Choice and calculation of the spiral cases, stators, guide vanes and draft tubes of turbines. The energy recovery factor of turbine. Nomenclature of turbines.

Explanatory exercises in the laboratory for hydraulic machines and energy systems, and numerical simulations:

Presentation of hydraulic turbine constructions and description of a particular turbine passage function. Installations for testing hydraulic turbines and description of their operation. Presentation of numerical experiment - the turbine flow calculation using the contemporary CFD techniques.

Project (carrying out the project based on instructions): Choice of turbine and calculation of its basic dimensions in accordance with the given input parameters.

prerequisite
Defined in the Curriculum

learning resources
Benišek, M.: Hydraulic Turbines, Faculty of Mechanical Engineering in Belgrade, 1998

Božić, I.: Hydraulic Turbines - Practical examples with extracts from theory, University of Belgrade Faculty of Mechanical Engineering in Belgrade, 2017

Božić, I.: Auditory exercises handouts

Laboratory hydraulic machines and energy systems - devices, installations for testing turbines, measuring equipment and exhibits

Faculty Computer Classroom

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 4
calculation tasks: 9
seminar works: 0
project design: 5
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 25
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Miroslav Benišek „Hidraulične turbine“, Mašinski fakultet u Beogradu, 1998
Ivan Božić „Hidraulične turbine - Praktični primeri sa izvodima iz teorije“, Mašinski fakultet u Beogradu, 2017
Берлит В „Гидровлические турбине“, Головное издателство „Виша школа“, Киев, 1977
Ковалев Н, „Справочник по гидротурбинам“, Машиностроение, Ленинград, 1984
Raabe J, „Hydropower“, VDI Verlag, GmbH, Düsseldorf, 1985

Hydropower measurements

ID: MSc-0927
responsible/holder professor: Ilić B. Dejan
teaching professor/s: Božić O. Ivan, Ilić B. Dejan, Janković Z. Novica, Čantrak S. Đorđe
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: hydropower engineering

goals
Measurements have a very significant role in engineering practice and research activities. The measurements in hydro-energy systems include measuring fluid flow quantities and energy characteristics of hydraulic machinery, in order to determine the energy performance of turbines, pumps, fans and other turbomachines. In framework of this subject, the characteristics of valves and methods for determining the cavitation characteristics of hydraulic machines and equipment are studied in detail.

learning outcomes
On successful completion of this course, students should be able to:

1. Organize and carry out testing of hydraulic machines (turbines, pumps, fans and turbocompressors) in the laboratory, following applicable international standards,

2. Process, present and analyze test results and calculate measurement uncertainty of the measured values,

3. Perform a comparative analysis of number of ways for measuring the energy parameters of hydraulic machines,

4. Recalculated efficiency from a model to a prototype of turbine,

5. Explain the calibration of pressure, flow and torque measuring devices, process the measurement results of calibration and calculate measuring uncertainty following applicable international standards and recommendations.

theoretical teaching
- The importance of testing in hydro-energy systems. Model testing of hydraulic machineries;

- Standards and recommendations for model tests. Overview of measuring parameters;

- Turbine model test in the laboratory;

- Energy and cavitation characteristics determination of turbine models - the universal characteristics;

- Turbine test in hydro-power plants;

- Pump model tests in the laboratory;

- Energy and cavitation characteristics determination in pump models - the universal characteristics;

- Pumps test in pumping stations;

- Fan test in laboratory and ventilation systems;

- Compressor test in laboratory and compressor systems;

- Hydro-mechanical equipment test in the laboratory;

- Energy and cavitation characteristics determination of hydro-mechanical equipment (valves).

practical teaching
Auditory exercises:

- Measurements of physical quantities in hydro-energy system;
- Determination of pump energy and cavitation characteristics;
- Determination of turbine energy and cavitation characteristics;
- Determination of pump energy and cavitation characteristics at pump station;
- Determination of the energy performance of turbines in hydro-power plant.

Laboratory Exercise:

- Calibration of measuring equipment;
- Determination of universal characteristics of the pump and turbine model;
- Fan test in laboratory and ventilation systems.

prerequisite
Requirements for examination: Pumps, Hydraulic turbines, Fans and turbocompressors.

Preferred: Mechanical engineering measurements and sensors.

learning resources
[1] Hand-outs,

[2] Installation for testing the energy and cavitation features of turbine models, small hydro-power plants and hydro-mechanical equipment,

[3] Pelton turbine test rig

[4] Installation for flow visualization, determing pump hydraulic characteristics, variety of pump control possibilities, determing duct hydraulic characteristics

[5] Installation for flow meter calibration by volume method, testing of pumps and hydro-mechanical equipment

[6] Installation for flow meter calibration by volume method (56 l/s)

[7] Test rig for defining energy characteristics of the axial fans and swirl flow in diffusers (swirl chamber)

[8] Test rig with booster fan for fan and fluid flow phenomena investigations

[9] Installation for calibrating pressure gauges

[10] Calibration tunnel for velocity and pressure probes

[11] Test rig for exploring swirl flow in straight ducts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 25
calculation tasks: 0
seminar works: 0
project design: 0

consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 10
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 0
laboratory exercises: 60
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Ilić D. B., Ćantrak Đ. S. (2017): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
Miroslav Benišek "Hydraulic Turbines," Mechanical Engineering in Belgrade, 1998.,

Hydropower plants and equipment

ID: MSc-0810
responsible/holder professor: Božić O. Ivan
teaching professor/s: Božić O. Ivan, Ilić B. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: hydropower engineering

goals
Achieving academic competence in the field of hydropower plants, equipment and hydro energy.

Obtaining practical knowledge in hydropower plants designing and the content of the technical project documentation.

Mastering knowledge of how to choose and calculate hydromechanical equipment installed in hydroelectric and pump stations.

Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.

Improving individual creative abilities in performing professional design of hydro energy systems.

learning outcomes
On successful completion of this course the students will be able to:

- define, plan and organize the phases of project design, build up and operation of hydropower plants within electro energy and water supply systems,

- design the optimal hydro mechanical equipment (trash racks, valves, pipes etc.),

- apply the empirical data to the choice and calculation of hydraulic machinery and equipment with the aim of high efficiency operation of hydro power plants and pump stations,

- analyze the transient operating regimes and unsteady fluid flow (water hammer) in various energy systems,

- collect, analyze and present the calculation results,

- choose the optimal solution to the specific case by analyzing more possible solutions from the point of energy and economy,

- work as a part of a team as well as demonstrate their entrepreneurial skills.

theoretical teaching
Significance and types of hydro plants in electric power and water management systems. Basic laws regarding the construction. Design of hydropower (HPP) and pump plants. HPP powerhouse. Hydromechanical equipment in power plants. Fundamentals of hydro-generators. Transients in hydropower plants. Pump stations. Selection and installation of pumps in the pump stations. Pump stations equipment. Complex hydro systems. Installation and calculation of piping. Water-hammer. Water-hammer calculation methods. Protection hydro plants from water-hammer. Fan and compressor systems. Small hydropower plants. Auxiliary systems in hydro plants. Energy and economic project analysis.

practical teaching
Hydroplants. The design phases and the accompanying technical documentation. Providing the data basis for the design. The basic parameters of power plants. The choice of turbine parameters during designing process. Practical calculation examples from hydromechanical systems design. Water-

hammer calculation examples. Sample calculation of water level oscillations in the water tank. Additional systems in plants. The examples of fan and compressor systems. Choice of types, number of pipelines and the pipes diameters. Trash rack and its cleaning mechanisms. Valve sample calculation.Valve cavitation.

Visiting hydro plants in the water management and electric power systems.

prerequisite
Defined in the Curriculum

learning resources
Benisek, M.: Lecture handouts (Hydro-mechanical plants, Hydro-mechanical equipment)

Bozic, I.: Auditory exercise handouts (Hydro-mechanical plants)

Božić, I.: Hydraulic Turbines - Practical examples with extracts from theory, University of Belgrade Faculty of Mechanical Engineering in Belgrade, 2017

Laboratory for hydraulic machines and energy systems - devices and installations.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 0
calculation tasks: 8
seminar works: 0
project design: 6
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 30
requirements to take the exam (number of points): 35

references
Benišek, M.: Hidraulične turbine, Mašinski fakultet u Beogradu, 1998
Đorđević, B.: Hidroenergetsko korišćenje voda, Građevinski fakultet, Beograd, 2003.

Ivan O. Božić „Hidraulične turbine - Praktični primeri sa izvodima iz teorije“, Mašinski fakultet u Beogradu, 2017
Raabe, J.: Hydropower - The Design, Use, and Function of Hydromechanical, Hydraulic, and Electrical Equipment, VDI-cVerlag GmbH, Düsseldorf, 1985
Ильиных, И.И.: Гидроэлектростании, Энергоатомиздат, Москва, 1988.

Machine design of pumps, fans and turbocompressors

ID: MSc-0445
responsible/holder professor: Nedeljković S. Miloš
teaching professor/s: Janković Z. Novica, Nedeljković S. Miloš, Čantrak S. Đorđe
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: hydropower engineering

goals
Mastering knowledge of engineering design of pumps, fans and turbochargers. Capacity to work in the design and development offices in the industry of pumps, fans, blowers and turbochargers. Training for innovation of design methods.

learning outcomes
After finishing this course, the students will be able to:

1. Conduct design calculations of pumps, fans and turbocompressors, applying different methods.

2. Make analysis of consequences of different approaches in design.

3. Use and analyze hydraulic, numerical and empirical data used in design calculations.

4. Model the geometries of pumps, fans and turbocompressors.

theoretical teaching
Calculation of radial pump rotating impeller. Meridian section of the impeller and determination of the flow grid. The horizontal projection of the impeller. Point by point design method. The method of conformal mapping. Model sections. Design and calculation of the spiral casing. Design of axial pumps. The choice of optimal characteristic coefficients. Application of the cascade theory for calculation of the axial pump impeller blades and stay vanes. Method of lifting surfaces. The Weing-Eckert method. Design of the inlet confusor (suction bell), diffuser and outlet bend. Determination of hydraulic, volumetric and mechanical losses of the pump. Axial and radial forces: origin, calculation, balancing. Sealing: types and applications. Bearing and construction. Calculation of pump characteristics. Specifics of fans design. Specifics of turbocompressors design. Optimal characteristic coefficients in axial compressors design. Calculation of radial impellers and thier design. The choice of materials and the calculation of strength of certain parts of turbochargers. Basic guidelines for designing of multi-stage turbochargers.

practical teaching
Project examples: Design calculation of radial pump rotating impeller. Shaping of the meridional section and determination of the grid. Formulating the horizontal impeller projection. Point by point method. The method of conformal mapping. Model sections. Design of inlet and outlet stay vanes. Design and calculation of the spiral casing. Application of the cascade theory for calculation of axial pump impeller and stay vanes. Method of lifting surfaces. Method Weing-Eckert. Shaping of impeller and stay vanes. Design of suction bell, diffuser and output bend. Bearing and construction. Specifics of fan design. Special specifics of turbocharger design.

prerequisite
Subjects passed: Pumps, Fluid Mechanics B. Knowledge of basic computer tools.

learning resources
Handouts for lectures and exercises.

Laboratory for hydraulic machines - equipment, installations, measuring equipment.

Faculty computer classroom.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 22
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 70
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 21

references

Mechanical engineering measurements and sensors

ID: MSc-0926
responsible/holder professor: Ilić B. Dejan
teaching professor/s: Ilić B. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: hydropower engineering

goals
Research, development and practice in science and engineering cannot be imagined without the experimental methods that are combined in the field of measurement techniques. The aim of this course is to provide basic and specific knowledge in the field of experimental methods necessary for mechanical engineers, with special reference to flow measurement techniques. The subject involves measuring the nonelectrical quantities in mechanical engineering and their transformation into electrical quantities using sensors. Through specific measurements in the laboratory, students are introduced to the field of practical experimental methods.

learning outcomes
On successful completion of this course, students should be able to:

1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,

2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,

3. Process and present the measurement results,

4. Calculate the measurement uncertainty,

5. Explain the calibration of velocity, pressure and flow measuring devices,

6. Describe the types and characteristics of sensors.

theoretical teaching
Theoretical lecturing is realized through the following core learning areas:

- Error of direct and indirect measurements. Measurement uncertainty.

- Theoretical basis of measurement non-compressible and compressible fluid flow.

- Measurement of pressure and velocity of fluid flow.

- Measuring velocity as vector quantities.

- Temperature measurements.

- Measurement of fluid flow.

- Measurement of humidity. Measuring the frequency of rotation, force, torque and power drive and driven machinery.

- Sensors (types, properties, characteristics, materials). Resistive, capacitive, inductive and generator sensors.

practical teaching
Auditory exercises:

- Errors of direct and indirect measurements of measurement quantities. Measurement uncertainty.

- Measurement of pressure and velocity of fluid flow. Pressure gauges and anemometers.

- Measuring velocity as vector quantities.

- Measuring compressible flow parameters.

- Measurement of fluid flow. Flow-meters.

- Sensors (types, characteristics, dynamic characteristics, materials).

- Resistant, capacitive, inductive and generator sensors.

Laboratory exercises:

- Determining the pressure distribution around the contour of the cylindrical probe,

- Cylindrical probes calibration,

- Measurements of temperature sensors.

prerequisite
Desirable: Thermodynamics, Fluid Mechanics, Physics and measurements.

learning resources
[1] M Benišek., M Nedeljkovic., R Kilibarda., Gerasimović D. "The measurement techniques. Exercises in flow measurements", Mechanical Engineering, Belgrade 2000.,

[2] Hand-outs from the written lectures,

[3] Ilić D. B., Ćantrak Đ. S. (2017): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade,Belgrade. (in Serbian),

[4] The experimental installation for velocity and pressure probe calibration, available in the laboratory of the Department,

[5] The experimental installation for calibration of the pressure devices, available in the laboratory of the Department,

[6] Laboratory of the Institute of physics of Technical faculties.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 15
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5

test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 22
calculation tasks: 3
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Ilić D. B., Ćantrak Đ. S. (2017): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
Vušković I .: "Fundamentals of measurement techniques", Mechanical Engineering, University of Belgrade, Belgrade, 1977.
Holman J.: "Experimental methods for engineers", Internatiional student edition, Mc Graw – Hill Company, 1984.
Tropea C., Yarin A., Fosss J. (Eds.): Springer Handbook of Experimental Fluid Mechanics, Springer-Verlag, Berlin, Heidelberg, 2007.
Stankovic D .: "Physical Technical measurements - sensors", Electrical Engineering, Belgrade, 1997.

Pumps

ID: MSc-0443
responsible/holder professor: Nedeljković S. Miloš
teaching professor/s: Janković Z. Novica, Nedeljković S. Miloš, Čantrak S. Đorđe
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: hydropower engineering

goals
Mastering knowledge of engineering applications of pumps as machines for raising of fluid energy. Capacity to work in practice on energy installations, as well as design of installations that include a pump as a built-in element with its function.

learning outcomes
After finishing this course, the students should be able to:

1. Know and recognize the types and designs of pumps,

2. Calculate the pump/system energy parameters and energy balancing,

3. Calculate and apply the dimensionless parameters - characteristic performance factors,

4. Determine the pump/system working point,

5. Apply the energy characteristics of pumps for establishment of operating regimes, as well as in their regulation.

6. Calculate the pump and the system cavitation characteristics,

theoretical teaching
Description of pumps. Energy balance. Definition of the internal work, impeller work and useful work. Flow work per unit - the head. Determination of the head by definition and along the pipeline route. Euler equation for turbomachinery. The impact of the impeller outlet angle on the impeller head and on the reaction factor. Impeller head reduction - the impact of a finite number of blades. Powers and efficiencies of pumps. The laws of similarity. Characteristic ceofficients of pumps. Classification of pumps by types. Cavitation. Cavitation reserve. The cavitation coefficient. Suction head determination. The influence of fluid properties on the characteristics of pumps - the impact of fluid viscosity on pump performance. The calculation of basic dimensions of pumps. Matching of pump performance curves with installation characteristics and regulation of pumps. Selection of pumps. Testings of pumps. Application of pumps in various plants. Piston pumps - description, classification, and the working principle. Nonuniformity of flow rate. Indicator diagram. Determination of power and suction height. Description of the rotating-piston pumps.

practical teaching
Calculation examples of the lectured material: The energy balance. Determination of head by definition and along the pipeline route. Euler equations for turbomachines. Impeller head reduction. Powers and efficiencies of pumps. The laws of similarity. Characteristic coefficients of pumps. Cavitation reserve. Suction head determination. Pumps matching and regulation. Pumps in various plants.

Demonstrative laboratory exercises: Institute (laboratory) for hydraulic machinery - showing PF constructions and description of the role of individual parts. Pump installations and description of their work.

prerequisite

The Fluid Mechanics B exam obligatory passed. Desirable that the student has passed the examination of the subject Introduction to Energy Engineering.

learning resources

Textbook: Protic Z, Nedeljkovic M. Pumps and fans. Problems, solutions, theory, 6th ed. Faculty of Mechanical Engineering University of Belgrade, Belgrade 2010.

Handouts for the exercises.

Laboratory for hydraulic machines - equipment, installations, measuring equipment.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 26
laboratory exercises: 2
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 10
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 70
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 21

references

Renewable energy resources - small hydropower plants

ID: MSc-0928
responsible/holder professor: Božić O. Ivan
teaching professor/s: Božić O. Ivan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: hydropower engineering

goals
Achieving academic compentence in the field of small hydropower plants, hydromechanical equipment and hydro energy.

Obtaining practical knowledge in small hydropower plants designing and the content of the technical project documentation.

Mastering knowledge of how to choose and calculate hydromechanical equipment installed in small hydroelectric stations.

Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.

Improving individual creative abilities in performing professional design of small hydropower plants.

learning outcomes
On successful completion of this course the students will be able to:

- define, plan and organize the phases of project design, build up and operation of small hydropower plants,

- apply the empirical data to the choice and calculation of hydraulic turbines and equipment (trash racks, valves, pipes etc.) with the aim of high efficiency operation of small hydro power plants,

- check the adopted geometry and operating characteristics by basic analysis of the transient operating regimes and water hammer phenomenon,

- collect, analyze and present the calculation results,

- choose the best solution to the specific case by analyzing more possible solutions from the point of energy efficiency,

- work as a part of a team as well as demonstrate their entrepreneurial skills.

theoretical teaching
Renewable energy resources. Significance, historical development and types of small hydro plants (SHPP). Opportunities for hydropower use in the world and in Serbia. Law regulations regarding the SHPP construction and electricity generation therein. Input data basis for SHPP design. Main SHPP parameters. SHPP design. Piping installation and calculation. SHPP powerhouse. Small, mini and micro hydraulic turbines. Hydromechanical equipment in SHPP. Fundamentals of governing systems and electrical equipment. Transients in small hydropower plants. Waterhammer. Waterhammer calculation methods. SHPP waterhammer protection. Auxiliary systems in small hydro plants. Energy and economic project analysis.

practical teaching
The design phases and the accompanying technical documentation. Analysis of the input data basis for the design. The basic parameters of SHPP. The calculation of main turbine parameters during designing process (dimensions of runner, spiral case, draft tube, suction head, reference level of turbine in relation

to tail water level, minimum, nominal and maximun power). Turbines' energy and cavitation characteristics. Turbine regulation and governing systems. Practical calculation examples from hydromechanical systems design. Additional systems in SHPP. Waterhammer calculation examples. Choice of types, number of pipelines and the pipes diameters. Trash rack and its cleaning mechanisms. Valve sample calculation. Determination of hydraulic measurements methods.

Demonstration of small Pelton turbine operation in the Laboratory of Hydraulic Machinery and Energy Systems. Visiting small hydro plants in the electric power systems.

prerequisite
It is desirable to have some of the BSc or MSc subjects on Hydraulic machinery and energy systems department passed or attended.

learning resources
Benisek, M.: Lecture handouts (Hydro-mechanical plants, Hydro-mechanical equipment)

Božić, I.: Hydraulic Turbines - Practical examples with extracts from theory, University of Belgrade Faculty of Mechanical Engineering in Belgrade, 2017

Bozic, I.: Auditory exercise handouts (Hydro-mechanical plants)

Laboratory for hydraulic machines and energy systems - devices and installations.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 0
calculation tasks: 8
seminar works: 0
project design: 6
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 25
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Benišek, M.: Hidraulične turbine, Mašinski fakultet u Beogradu, 1998
Đorđević, B.: Hidroenergetsko korišćenje voda, Građevinski fakultet u Beogradu, 2001.
Ivan O. Božić „Hidraulične turbine - Praktični primeri sa izvodima iz teorije", Mašinski fakultet u Beogradu, 2017
Warnick, C.C.: Hydropower engineering, Prentice-Hall.Inc, Englewood Cliffs, New Jersey, 1984
Ristić B., Milenković D.: Male hidroelektrane-vodne turbine, Naučna knjiga, Beograd , 1996

Skill Praxis M - HEN

ID: MSc-1210
responsible/holder professor: Ilić B. Dejan
teaching professor/s: Ilić B. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: hydropower engineering

goals
The goal of professional practice is that students in addition to theoretical work within subjects at the faculty get to know and experience the jobs in factories, institutes, laboratories and similar commercial enterprises and thereby gain insight into the activities to be performed. During the practice, students must keep a diary in which they enter a description of the tasks performed, and write down their conclusions and observations. Following the practice, students must write a report that is to be discussed about with the subject teacher.

learning outcomes
On successful completion of this course, students should be able to:

1. Write a report with a completed skill praxis,

2. Describe the operation and organization of the appropriate energy system or facility,

3. Demonstrate acquired practical experience and skills, related to specific jobs in the appropriate energy systems or facilities,

4. Acquire and develop team skills in work environment (communication with colleagues, professional ethics, etc.).

theoretical teaching
The course content is practical work, which consists of spending working time in certain organizations that perform various activities in mechanical engineering. The choice of a theme as well as a business or research organization is made in consultation with the concerned teacher. Students may perform their practice in: design and energy consulting profession organizations, organizations that produce and maintain power equipment, organizations that build and maintain power plants, waterworks companies and laboratories of the Department of hydraulic machines and power systems.

practical teaching
In the design and consultancy organizations, students are introduced to the process of design and analysis of power plants, acquire practical knowledge of engineering graphics, use of modern computer programs for designing and analyzing equipment and facilities, implementation of measures for rational use of energy and environmental protection and others. In organizations that produce and maintain power equipment they are acquainted with the process of equipment production, technological lines of production, quality control, and others. Within the companies for the construction and maintenance of power plants they acquire knowledge about the organization of construction, layout of equipment and technological systems in plants, and others. In power plants they get to know the appropriate processes, technology systems, fixtures and equipment, methods, process analysis, measurement of process parameters, operating the plant, and others. In the laboratories of the Department of hydraulic machines and power systems they can become familiar with the available equipment and measuring equipment.

prerequisite

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learning resources

[1] Instructions for writing reports from professional practice,

[2] Guidelines for handling the equipment and facilities in the laboratories of the Department,

[3] Installation for testing the energy and cavitation features of turbine models, small hydro-power plants and hydro-mechanical equipment, available in the laboratory of the Department,

[4] Pelton turbine test rig

[5] Facility for studying cavitation phenomenon in pumps and hydrofoils with the visualization possibility

[6] Installation for flow visualization, determing pump hydraulic characteristics, variety of pump control possibilities, determing duct hydraulic characteristics

[7] Installation for flow meter calibration by volume method, testing of pumps and hydro-mechanical equipment

[8] Installation for flow meter calibration by volume method (56 l/s)

[9] Test rig for defining energy characteristics of the axial fans and swirl flow in diffusers (swirl chamber)

[10] Test rig with booster fan for fan and fluid flow phenomena investigations

[11] Installation for calibrating pressure gauges

[12] Calibration tunnel for velocity and pressure probes

[13] Test rig for exploring swirl flow in straight ducts

[14] PIV system

[15] LDA system

[16] CNC

number of hours: 90

active teaching (theoretical): 0
lectures: 0
elaboration and examples (revision): 0

active teaching (practical): 80
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 80
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 0

colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 70
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Theory of Turbomachinery

ID: MSc-1000
responsible/holder professor: Ilić B. Dejan
teaching professor/s: Ilić B. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: hydropower engineering

goals
Introduction of theoretical knowledge of fluid flow in turbomachinery. Studying of energy and exploitation characteristics of turbomachinery in dimensional and

non-dimensional forms and their application in mechanical systems. Obtaining of practical skills application of hydraulic turbines, pumps, fans and turbocompressors in power systems.

learning outcomes
On successful completion of this course, students should be able to:

1. Identify and describe the different types and designs of turbomachinery (hydraulic turbines, pumps, fans and turbocompressors),

2. Explain the flow process and exchange of energy in turbomachinery,

3. Identify and analyze energy and exploitation characteristics of turbomachinery,

4. Explain the cavitation phenomenon in pumps and hydraulic turbines.

theoretical teaching
- Description, classification, and the working principle of turbomachinery.

- The principles of energy exchange анд energy balance in turbomachinery. Phenomena in fluid flow in turbomachinery.

- The theoretical basis of thermodynamic. Multi-stage compression in the compressors (work and efficiencies).

- Definition of the internal work and impeller work. Euler equation for turbomachinery. Specific hydraulic energy.

- The impact of the impeller outlet angle on the impeller head and on the reaction factor.

- Impeller head reduction - the impact of a finite number of blades.

- Powers and efficiencies of pumps. Losses in turbomachinery.

- The laws of similarity. Characteristic coefficients of turbomachinery.

- Cavitation - phenomenon, stages. Cavitation reserve. The cavitation coefficient.

- Control of turbomachinery.

- Hydro (aero) profiles. Method of lifting surfaces.

practical teaching
Turbomachinery in hydraulic, ventilation and compressor systems. Different types of runners and impellers. Exploatation of turbomachines. Laboratory exercises - showing turbomachinery constructions and description of the role of individual parts. Calculation examples of the lectured material: Calculation of specific hydraulic energy of pumps, fans and compressors. Euler equations for turbomachines. Powers and efficiencies of turbomachinery. Operating characteristics of

turbomachinery. The laws of similarity and non-dimensionless characteristics. Cavitation reserve. Control of turbomachinery.

prerequisite
Compulsory examinations passed: Fluid Mechanics, Thermodynamics.

Preferred exams passed: Basis of Turbomachinery, Pumps and Fans.

learning resources
Lectures in written and partially in electronic form, handouts for the exercises.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 40
project design: 0
final exam: 50
requirements to take the exam (number of points): 30

references

INDUSTRIAL ENGINEERING

Database Systems

Design of logistic and warehouse systems

Engineering statistics

Ergonomic design

Ergonomic designing

Foreign language

Industrial engineering methods and techniques application in naval architecture

Industrial logistic

Industrial Management

Man - machine system design

Management Information Systems

Operations Research

Organization Design

Production and Operations Management 2

Quality improvement in production processes - Lean Six Sigma

Risk management in Terotechnology

Skill Praxis M - IIE

Techno-economic analysis and project management

Database Systems

ID: MSc-0521
responsible/holder professor: Misita Ž. Mirjana
teaching professor/s: Misita Ž. Mirjana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
The aim of this course is to prepare students for working with complex databases in production companies. The aim of this course is usage of industrial engineering methods and techniques in the creation of different database queries and scripts. Also, the aim of course is usage of complex database for improvement of decision-making process and management of business-production system.

learning outcomes
Upon successful completion of this course, students should be able to:

- use SQL language,

- write queries for application industrial engineering methods using SQL language (For example: The level of utilization of machine capacity, the efficiency of production processes, ABC analysis, etc.).

- Analyze the results obtained by the queries established for business analysis,

- Estimates of efficacy of queries a established for the different methods of industrial engineering.

theoretical teaching
1. Basic concepts of - database, databases, knowledge bases. Types of databases - hierarchical, network, relational model, object-oriented data model. Systems for database management. Standard SQL language. SQL data types. Queries. Examples of SQL functions.

2. Methods and techniques of industrial engineering - scripts in the SQL language. Defining the scripts for: rationalization of operating costs (QC diagram, critical point, ABC method) for calculating the machine capacity efficiency degree, and other scripts that involve application of industrial engineering methods and techniques in the analysis of operations of the relevant business-production system.

practical teaching
Design of database, tables and indexes. Using of SQL query. Operators and functions in the SQL language. For the relevant example in practice, by using SQL language, defining scripts for: rationalization of operating costs (QC diagram, critical point, ABC method) for calculating the degree of efficiency of machine capacity, and other scripts that involve application of industrial engineering methods and techniques in the analysis of operations of the relevant business-production system.

prerequisite
Enrolled 3rd semestar of Master study.

learning resources
1. Handouts,

2. Computer classroom,

3. Software tool: MySQL,

4. Resuources form http://www.mysqul.com/

5. Database from concrete enterprise, in order to get practice on real example.

number of hours: 75

active teaching (theoretical): 26
lectures: 26
elaboration and examples (revision): 0

active teaching (practical): 39
auditory exercises: 0
laboratory exercises: 39
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 10

references
Johnson, J., Database - Models, Languages, Design, Oxford University Press, Oxford, 1997.
Beaulieu, A., Learning SQL, O'Relly Media, 2009.
Geherke, J., Database Management System, McGraw-Hill, New-York. 2003.

Design of logistic and warehouse systems

ID: MSc-1370
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa, Petrović B. Dušan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
Achieving competency and academic skills in the process of industrial system design. Special emphasis is focused on development of creative skills and overwhelm with specific practical skills needed for professional practice using operational research methods, procedures of analysis and synthesis for obtaining final goal which is optimal practical solution.

learning outcomes
Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of solutions in design process based on knowledge applying in practice using professional ethics as well as development of crucial and self-critical thinking and approach.

theoretical teaching
Logistic system in industrial environment (connection of production system with transport system, management of demand and purchase and warehouse system). Design system documentation (fusibility study, conceptual solution, conceptual design, tender documentation, main technological-mechanical project, other main projects, final contractor project and project of carried out state). Previous analysis needed for system design (general conditions for urban planning, logistics and transport connections, energetic potential). Design process procedure. Project realisation and generation of results.

practical teaching
Audit lessons (Introduction in design process for defined logistic-distribution system. Activity analysis for forming conceptual solution and conceptual design, activities connected with choosing of technological and other equipment, activities on forming main technological-mechanical project and final contractor project).

Project workmanship (Workmanship of the logistic-distribution system project. Defining of necessary parameters and surroundings for the given system design. Defining of needed system capacities. Forming of assignments for the other projects. Realisation of main technological-mechanical project).

prerequisite
There is no special conditions needed for course attending.

learning resources
1. Bugaric, U., Petrovic, D.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011. (in print)

3. Bugaric, U.: Methodology for analysis of single position machines work, Foundation Andrejevic, Belgrade, 2003.

4. Zrnić, Đ., Petrović, D.: Factory design – assortment of solved examples, Faculty of Mechanical engineering Belgrade, Belgrade, 1990.

5. Zrnić, Đ., Petrović, D.: Stochastic process in transport, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.

6. Practical instruction in industrial environment.

7. Personal computers.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 4
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 26
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 30

references
Asimow, M.: Introduction to Design, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
Hall, A. D.: A methodology for systems engineering, Van Nostrand, Princeton, New Jersey, 1962.
Kleinrock, L.: Queueing Systems, Volume I: Theory, John Wiley & Sons, New York, 1975.
Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.

Engineering statistics

ID: MSc-1171
responsible/holder professor: Veljković A. Zorica
teaching professor/s: Veljković A. Zorica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
First step include descriptive statistics. Next step is to indentify problem to be solved, followed by choose of adequate methodology and solving problem using procedure appropriate procedure, following by mathematical and engineering conclusions. Engineering conclusions are the base for results interpretation and withdrawing adequate conclusions.

learning outcomes
After successfully completed course, students should be able to define the problem, identify and apply adequate statistical procedures and obtain competent answers. During the course students master the procedures for use of adequate parametric and non parametric methods as well as introduction in programming in R. It is expected that students could be able for interpretation of statistical results for their use in practical problems.

theoretical teaching
Course include following subjects: Basic definitions in statistics; Descriptive statistics; Basics of discrete and continuous probability distributions for random variables; Parameter tests of hypothesis that include one and two sample tests for means, proportion and variance. Non-parametric testing include goodness of fit by Kolmogorov test, comparison tests for distributions such as Mann Whitney test, Kolmogorov-Smirnov test and tests for median and difference of median; One-way and two-way analysis of variance for parametric examination; Non-parametric analysis of variance, Simple linear and multiple regression and correlation for parametric testing and Spearman test and Orthogonal polynomials as an examples of non-parametric regression and correlation examination.

practical teaching
Exercises follow the contents of lectures by examples and problem solving in order to identify and set the problem adequately, followed by identification of appropriate statistical method and procedure up to interpretation of the results and drawing the conclusions. For all methods is required adequate R programming. Exercises are based on examples that teach students to use specially developed tables for procedures algorithms and tables with formulas for better and efficient problem solving. Proper practical interpretation of results and drawing of conclusions is emphases.

prerequisite
According the Industrial Engineering curriculum

learning resources
All materials for successful following of the course - handouts and other materials are distributed to students before lectures in electronic form.

Radojević S, Veljković Z, Kvantitativne metode, CD. MF

number of hours: 75

> **active teaching (theoretical):** 25
> lectures: 20
> elaboration and examples (revision): 5

active teaching (practical): 40
auditory exercises: 20
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 9
test, with assessment: 0
final exam: 1

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 31

references
Radojević S, Veljković Z, Kvantitativne metode, CD. MF
Montgomery, DC, Runger, GC Applied Statistics and Probability for Engineers, Fourth Edition, Wiley, 2007

Ergonomic design

ID: MSc-1041
responsible/holder professor: Žunjić G. Aleksandar
teaching professor/s: Žunjić G. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: industrial engineering

goals
Students should acquire specific practical skills that include an integrated ergonomic approach for the design of a comprehensive solution to different problems. The aim of this course is the acquisition of basic academic knowledge in the field of ergonomic design, which can be used for design of different products, as well as for redesigning and improvement on the system man - machine.

learning outcomes
Upon successful completion of this course, students should be able to:

• Identify the different types of errors in the man - machine system and to apply adequate solutions aimed at eliminating of errors

• Design the indicators based on the application of ergonomic recommendations

• Design the controls based on the application of ergonomic recommendations

• Apply the ergonomic principles and recommendations on the design of the working environment and to conduct an assessment of the working conditions based on the application of experimental procedures

• Recognize the benefits and learn about the possibilities of applying software intended for computer-aided ergonomic design

• Apply the anthropometry in designing various products and transportation systems

• Perform ergonomic assessment of an interface

• Understand and recognize the ergonomic characteristics of the quality of products

• Identify the factors that affect the comfort and safety of a vehicle from the ergonomic aspect

theoretical teaching
Introduction to ergonomic design. Management of errors in the man - machine system. Design of indicators.Design of controls.Application of anthropometry in ergonomic designing.Ergonomic product design and evaluation of interface. Comfort and safety of vehicles. Computer supported ergonomic design (CAED).

practical teaching
Project task - Anthropometric designing of products. Auditory exercise - Design of cabins of cranes and hoists. Laboratory exercise - Assessment of design solution of the working environment conditions.

prerequisite
The necessary condition for attending the course is that the student have enrolled to the appropriate semester.

learning resources
Žunjić A, 2016, Script for Ergonomic design, Faculty of Mechanical Engineering, Belgrade. Žunjić A. and Ćulić M., 2007, Practicum for laboratory exercises in industrial ergonomics, Faculty of Mechanical engineering, Belgrade - available in the bookstore and library of the Faculty of Mechanical Engineering.

Klarin M. and Žunjić A., 2007, Industrial ergonomics, textbook, Faculty of Mechanical engineering, Belgrade - available in the bookstore and library of the Faculty of Mechanical Engineering. Sound level meter, konimeter, psychrometer, lux meter, anthropometric measuring equipment.

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 21
auditory exercises: 2
laboratory exercises: 8
calculation tasks: 0
seminar works: 0
project design: 8
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 1
colloquium, with assessment: 0
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 40

references
Žunjić A, 2016, Script for Ergonomic design, Faculty of Mechanical Engineering, Belgrade.
Handbook of human factors and ergonomics in consumer product design: uses and applications, 2011, Edited by Karwowski W., Soares M. and Stanton N., Taylor & Francis, London.
Sanders M. and McCormick E., 1993, Human factors in engineering and design, McGraw - Hill, Singapore.
Woodson W., 1981, Human factors design handbook, McGraw-Hill Book Company, New York.

Ergonomic designing

ID: MSc-0417
responsible/holder professor: Žunjić G. Aleksandar
teaching professor/s: Žunjić G. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: industrial engineering

goals
The aim of this course is the acquisition of basic academic knowledge in the field of ergonomic designing, which can be used for designing of different products, as well as for redesigning and improvement of system man - machine - environment. Students should acquire specific practical skills that include an integrated ergonomic approach for the purpose of a comprehensive settlement of various designing problems.

learning outcomes
Upon successful completion of this course, students should be able to:

- Apply ergonomic approach to all stages of the design process, during the design of simple or complex systems
- To apply various ergonomic tools for the purpose of realization of a project
- Design the indicators based on the application of ergonomic recommendations and carry out the assessment of the adequacy of indicators based on the application of the experimental procedure
- Design the controls based on the application of ergonomic recommendations
- Apply the ergonomic principles and recommendations on designing workplaces
- Apply the ergonomic principles and recommendations on the design of the working environment and to conduct an assessment of the working conditions based on the application of experimental procedures
- Recognize the benefits and learn about the possibilities of applying software intended for computer-aided ergonomic design
- Apply the anthropometry in designing various products and transportation systems
- Perform ergonomic assessment of an interface
- Understand and recognize the ergonomic characteristics of the quality of products
- Identify the factors that affect the comfort and safety of a vehicle from the ergonomic aspect
- Carry out the selection of the appropriate ergonomic method for design or evaluation of a system

theoretical teaching
Introduction to ergonomic designing. The ergonomic approach to designing of complex systems. Ergonomic tools for managing and implementation of engineering projects. Designing of indicators. Designing of controls. Workplace designing. Designing of conditions of the working environment. Computer-supported ergonomic designing (CSED). Application of anthropometry in the ergonomic designing. Ergonomic product designing and evaluation of interfaces. Safety and comfort of vehicles. Ergonomic research methods.

practical teaching
Writing of a seminar paper - each student selects one of a number of topics, for which he is writing seminar paper in the form of professional work. The first laboratory exercise: Assessment of conditions of working environment - the criteria for assessing of conditions of working environment are presented and carries out the assessment of the conditions of a working environment at the selected workplace. The project task - Application of anthropometry in designing. The second laboratory exercise: Readability of analogue visual displays - the criteria for the assessment of readability are presented and testing of analogue visual displays is performed in the laboratory conditions.

prerequisite
The necessary condition for attending the course is that the student have enrolled to the appropriate semester.

learning resources
Žunjić A. and Ćulić M., 2007, Practicum for laboratory exercises in industrial ergonomics, Faculty of Mechanical engineering, Belgrade - available in the bookstore and library of the Faculty of Mechanical Engineering. Klarin M. and Žunjić A., 2007, Industrial ergonomics, textbook, Faculty of Mechanical engineering, Belgrade - available in the bookstore and library of the Faculty of Mechanical Engineering. Tachistoscope, sound level meter, konimeter, psychrometer, lux meter, anthropometric measuring equipment, available in the lab. 417.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 11
calculation tasks: 0
seminar works: 8
project design: 6
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 3
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 20
project design: 10
final exam: 40
requirements to take the exam (number of points): 40

references

Žunjić A. and Ćulić M., 2007, Practicum for laboratory exercises in industrial ergonomics, Faculty of Mechanical engineering, Belgrade.
Klarin M. and Žunjić A., 2007, Industrial ergonomics, textbook, Faculty of Mechanical engineering, Belgrade.
Woodson W., 1981, Human factors design handbook, McGraw-Hill Book Company, New York.
Handbook of human factors and ergonomics in consumer product design: uses and applications, 2011, Edited by Karwowski W., Soares M. and Stanton N., Taylor & Francis, London.
Sanders M. and McCormick E., 1993, Human factors in engineering and design, McGraw - Hill, Singapore.

Foreign language

ID: MSc-0805
responsible/holder professor: Vesić-Pavlović S. Tijana
teaching professor/s: Vesić-Pavlović S. Tijana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: oral
parent department: industrial engineering

goals
Mastering English terms in the field of mechanical engineering and gaining skills for using professional literature in English, which contributes to students' active professional development and lifelong learning.

learning outcomes
Upon the completion of this course, students will be able to:

- use advanced professional vocabulary in both written and oral English language,

- write an abstract in English,

- analyze a scientific paper in English in terms of characteristic constructions.

theoretical teaching
Thematic contents in different branches of mechanical engineering, focusing on characteristic constructions and vocabulary in professional oral and written language. Mastering the formulations used in scientific papers in different fields of mechanical engineering. The structure of a scientific paper in English.

practical teaching
Oral and written exercises, interpreting charts and schemes in English. The presentation of a chosen scientific paper in English, making summaries, writing biography and job application.

prerequisite
Defined by the curriculum of the study programme/module.

learning resources
1. M. Dunn, D. Howey, A. Ilic. English for Mechanical Engineering in Higher Education Studies. Garnet Education, Reading, 2010.

number of hours: 30

active teaching (theoretical): 15
lectures: 10
elaboration and examples (revision): 5

active teaching (practical): 10
auditory exercises: 5
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 50
final exam: 40
requirements to take the exam (number of points): 20

references

M. Ibbotson, Cambridge English for Engineering, Cambridge University Press, Cambridge, 2008.
M. Ibbotson, Professional English in Use: Engineering. Technical English for Professionals. Cambridge University Press, Cambridge, 2009

Industrial engineering methods and techniques application in naval architecture

ID: MSc-1247
responsible/holder professor: Spasojević-Brkić K. Vesna
teaching professor/s: Misita Ž. Mirjana, Spasojević-Brkić K. Vesna
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: industrial engineering

goals
The aims of the course are to familiarise students with the basic methods and techniques of industrial engineering which can be in use to enhance efficiency and effectiveness in Naval Architecture. Those methods and techniques will enable students to develop organisational and management skills for planning, budgeting, organising, directing and controlling of tasks, people and resources and managing quality, cost, time and risks.

learning outcomes
Successful mastering of this study program strengthens students' understanding of importance of organisational and management skills in the engineering activities and prepares them for commercial leadership in Naval Architecture. The acquisition of basic modern theoretical concepts and empirical methods and techniques in Industrial Engineering relevant for Naval Architecture is stressed.

theoretical teaching
Introduction to Industrial Engineering. Short-Term, Medium-Term & Long-Term Planning. Quality Planning. Organisational Planning. Risk Management planning. Procurement Planning. Methods and techniques of project planning. Organisational structuring. Quality and Risk Management Standards. Program evaluation and review technique (PERT) and critical path method (CPM). Linear programming. Gant's charts. SWOT Analysis (Strengths, Weaknesses Opportunities, Threats). Balanced Scorecard (BSC). Ishikawa diagram (Cause-and-effect diagram). Pareto chart. FMEA (Failure Modes and Effects Analysis). FTA (Failure Tree Analysis).

practical teaching
Auditorial exercises on application of PERT and CPM method in project of shipbuilding, development of Gant's Charts and linear programming technique for project of shipbuilding. Workshop on Quality and Risk Management Standards clauses and systems documents (teamwork tasks). Each student implements each method/technique in its own practical example, thorough laboratory exercise – PERT/CPM, Linear programming, Gant's chart, SWOT, BSC, Ishikawa diagram, Pareto chart, FMEA and FTA.

prerequisite
-

learning resources
Handouts and tutorials. Using the Internet and other literature recommended by the lecturer is also desirable, especially for the preparation of discussions and workshops.

number of hours: 30

> **active teaching (theoretical):** 13
> lectures: 10
> elaboration and examples (revision): 3
>
> **active teaching (practical):** 13
> auditory exercises: 4
> laboratory exercises: 0

calculation tasks: 4
seminar works: 0
project design: 5
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 4
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Gavriel Salvendy (Ed.) 2007, Industrial Engineering Handbook, John Wiley & Sons Ltd.
Sage, A. P., & Rouse, W. B. (Eds.). (2009). Handbook of systems engineering and management. John Wiley & Sons.
Swanson, R. (1995). The quality improvement handbook: team guide to tools and techniques. CRC Press.
Tonchia, S., Tonchia, & Mahagaonkar. (2018).Industrial project management. Springer.
Handouts and tutorials.

Industrial logistic

ID: MSc-1369
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa, Petrović B. Dušan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
Achieving competency and academic skills in the process of industrial system design. Special emphasis is focused on development of creative skills and overwhelm with specific practical skills needed for professional practice using operational research methods, procedures of analysis and synthesis for obtaining final goal which is optimal practical solution.

learning outcomes
Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of solutions in design process based on knowledge applying in practice using professional ethics as well as development of crucial and self-critical thinking and approach.

theoretical teaching
Logistic system in industrial environment (role of logistic system in industry, functions which system must achieved and its benefit for industry). Elements of logistic system (production based on end user demand, distribution and warehouse systems). Basic sub-systems of logistic system (production with defined capacity, transport with defined technology and distribution warehouse system). Place and role of the warehouse in logistic system. Application and effects of application of logistic systems in industry (territory coverage with defining location of production and end user, reduction of transport and storage costs and increase of flexibility towards end user).

practical teaching
Audit lessons (Introduction in design process for defined logistic system – defining elements of logistic system and basic sub-systems for chosen logistic system. Introduction in warehouse design of palletized goods – defining of: reception area, main warehouse, distribution – order picking, shipping and warehouse management system).

Project workmanship (Determining of the optimal location of the logistic system in macro surrounding – positioning of warehouse regarding to production and end user as a function of transport system. Project of warehouse for palletized goods - defining of: packing and capacity, work technology, layout, reception and shipping and warehouse management system).

prerequisite
There is no special conditions needed for course attending.

learning resources
1. Bugarić, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011. (in print)

3. Zrnić, Đ., Petrović, D.: Factory design – assortment of solved examples, Faculty of Mechanical engineering Belgrade, Belgrade, 1990.

4. Zrnić, Đ., Petrović, D.: Stochastic process in transport, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.

5. Bloomberg, D. J., LeMay, S. B., Hanna, J. B.: Logistics, Prentice Hall, New York, 2002.

6. Practical instruction in industrial environment.

7. Personal computers.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 30

references
Asimow, M.: Introduction to Design, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
Hall, A. D.: A methodology for systems engineering, Van Nostrand, Princeton, New Jersey, 1962.
Cooper, B. R.: Introduction to queueing theory (second edition), Elsevier North Holland, New York, 1981.

Industrial Management

ID: MSc-1043
responsible/holder professor: Dondur J. Nikola
teaching professor/s: Dondur J. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
The aim of this subject is that students get know basic principles, methods and techniques of management in general, and especially in industrial enterprises. The aim is that students adopt knowledge and skills which will be solid basis for further requiring competences for autonomous and responsible participation in processes of business decisions in contemporary conditions.

learning outcomes
To get know of content Industrial Management the students get know modern knowledge from theory and practice of management in general, and especially in industrial enterprises, when accent is on achievement of competence to strengthen innovation as a key factor of competitivity in turbulent business environment, local and international.

theoretical teaching
Management and entrepreneurship: external environment, social responsibility and business ethics. Types of managers. Manager's roles. Industry and its transformations. Planning, strategic planning i strategic management. Forecasting and prognostication. Organization and organizing as managerial resources. Decision making as a problem solving process. Human resources as a asset of company. Conflicts and conflict management. Management of creativity and innovations. Basic principles of knowledge management. Leading. Styles of leading. Motivation. Systems of communications. Controlling as management feed-back. Industrial project management. Quality as management variable. Ecology management. Globalization and management.

practical teaching
The practical work is consisted from discussion and workshops with special topics as well as characteristic industrial cases from local and word practice. Special attention will be paid to the problem of innovations, especially to technological innovations as a factor of competitivity. Also, the questions of transition of management into leadership will be wider discussed, as well as other questions from contemporary business management. Beside that, practical work is used for preparation of seminar paper.

prerequisite
At least 50 points, when points from the practical exams are especially important.

learning resources
Beside cited literature and handouts, chosen internet links, as well as special prepared business cases, from local and the international practice, will be used.

Slobodan Pokrajac, Dragica Tomić, Management, (in Serbian), Alfa-graf, Novi Sad, 2011

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 20
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references
C.M.Chang, Engineering Management: Challenges in the New Millenium, Pearson Prentice Hall, New Jersey, 2005
John Jeston and Johan Nelis, Business Process Management: Practical Guidelines to Successful Implementations, Butterworth-Heinemann, 2006

Man - machine system design

ID: MSc-0520
responsible/holder professor: Žunjić G. Aleksandar
teaching professor/s: Žunjić G. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: oral
parent department: industrial engineering

goals
The aim of this course is the acquisition of basic academic knowledge in the field of man - machine system design, which can be used for designing of different products and industrial systems, as well as for redesigning and improvement of system man - machine - environment. Students should acquire specific practical skills that include an integrated ergonomic approach for the purpose of a comprehensive settlement of various designing problems.

learning outcomes
Upon successful completion of this course, students should be able to:

• Identify the main types of mechanical hazards

• Carry out the selection and to apply the basic types of safety protections on machines

• Perform the identification of all other types of hazards in the working environment and to implement hazard analysis in a man - machine system

• Apply basic procedures for hazard prevention

• To realize the complete program for realization of safe products within the organization

• Identify different types of errors in the man - machine system and to apply appropriate solutions aimed at eliminating errors

• Conduct an ergonomic evaluation of design solutions of manuals

• Design technical and project documentation in accordance with the ergonomic recommendations

theoretical teaching
Mechanical hazards and safe operation of machinery. Analysis of risk in the system man - machine and their prevention. Safety and reliability of products. Management of errors in the man - machine system. Ergonomics of designing of technical and project documentation. Recommendations for designing of technical and project documentation.

practical teaching
First project task - Identification of hazards in the workplace. Auditory exercise - Risk assessment in the man - machine system. Second project task - Ergonomic assessment of design solutions of manuals.

prerequisite
The necessary condition for attending the course is that the student have enrolled to the appropriate semester.

learning resources
Žunjić A., 2016, Script for man - machine system design, Faculty of Mechanical Engineering, Belgrade.

number of hours: 45

> **active teaching (theoretical):** 18
> lectures: 12
> elaboration and examples (revision): 6

active teaching (practical): 21
auditory exercises: 2
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 16
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 50
final exam: 40
requirements to take the exam (number of points): 40

references

Žunjić A., 2016, Script for man - machine system design, Faculty of Mechanical Engineering, Belgrade.
Handbook of human factors and ergonomics in consumer product design: uses and applications, Edited by Karwowski W., Soares M. and Stanton N., Taylor & Francis, London.
Sanders M. and McCormick E., 1993, Human factors in engineering and design, McGraw - Hill, Singapore.

Management Information Systems

ID: MSc-0523
responsible/holder professor: Misita Ž. Mirjana
teaching professor/s: Misita Ž. Mirjana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: industrial engineering

goals
The aim of this course is to introduce students to contemporary theoretical and practical aspects of management information systems. Students need to acquire practical knowledge and skills that will enable them to enhance the quality of decisions in the field of industrial engineering, by using the contemporary software tools. Decision support systems and expert systems.

learning outcomes
Upon successful completion of this course, students should be able to:

- Use software tools for decision support,

- Design models for decision-making process in DSS tools,

- Using expert systems in the field of industrial engineering,

- Projected base of knowledge in expert systems,

- Estimates of efficiency designed models in the specific case study.

theoretical teaching
The term of Management information system (MIS). Decision-making process. Methods and techniques used in decision-making by managers. New IT and Web applications in functional areas. Executive information systems. Decision support systems. Knowledge management. Intelligent support systems. Expert systems. Other intelligent systems. Hybrid systems. Contemporary software in management.

practical teaching
Task 1. By using software tools - decision support systems it is necessary to design models, generate a hierarchy of criteria and alternatives by introducing of qualitative and quantitative scales, introducing uncertainty, or by using functions to describe real problems in manufacturing practices. Conduct ranking according to the AHP or SMART methods. Sensitivity Analysis. Presentation of project assignment.

Task 2. By using an expert system shell it is necessary to design a knowledge base for the real engineering problem, link the production rules. Test the expert system. Presentation of project assignment.

Task 3. Connect the two previous project tasks and form a hybrid system. Presentation of project assignment.

prerequisite
Enrolled 1st semester of the Master study.

learning resources
1. Booк: Milanovic D. Dragan, Misita Mirjana, Information systems for management and decision making, Faculty of Mechanical Engineering, Belgrade, 2008.
2. Handouts,
3. Computer classroom,
4. Software packages: decision support system and expert system.

number of hours: 75

active teaching (theoretical): 26
lectures: 26
elaboration and examples (revision): 0

active teaching (practical): 39
auditory exercises: 0
laboratory exercises: 39
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 10

references
Milanovic D. Dragan, Misita Mirjana, Information systems for management and decision making, Faculty of Mechanical Engineering, Belgrade, 2008
Turban E., Aronson J., Decision Support and Business Intelligence Systems, Pearson International Edition, 9th edition, 2010.

Operations Research

ID: MSc-0421
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: industrial engineering

goals
Course goal is overwhelm with academic and scientific methods and quantitative techniques for obtaining alternative (optimal) solutions of real world problems on which basis user can perform analysis and synthesis of given solutions, make decision and predict consequences.

learning outcomes
Solution of concrete problems with application of scientific methods, procedures and techniques using analysis, synthesis and prediction of solutions and consequences as well as overwhelm with methods, procedures and research processes and application of knowledge (gained skills) in practice.

theoretical teaching
Introduction. Problem classification. Linear programming (graphical solution, simplex method, dual theory, sensitivity analysis). Transportation problem (open and closed). Linear regression (Least square method). Nonlinear programming (definition of convex function and set, one-variable and multivariable unconstrained and constrained optimization, Karush-Kuhn-Tucker (KKT) conditions, Gradient Search Procedure). Quadratic programming. Dynamical programming, Project management (structure analysis, time analysis using PERT/CPM, critical path, cost analysis – PERT/Cost). Service systems – Queuing theory (queuing theory models – single and multi server with out and with partial and complete help between servers, with finite and infinite source of customers, optimisation of service systems). Simulation of service systems (approach to simulation, Monte Carlo method, generation of random numbers, processing and presentation of simulation results). Decision analysis. Forecasting (forecasting methods).

practical teaching
Audit lessons (examples of linear programming, transportation problem, linear regression, nonlinear programming, quadratic programming, dynamical programming. Examples of project management – structure analysis, time analysis cost analysis. Examples of application of queuing theory models – finite and infinite source of customers, single and multi server without and with partial and complete help between servers. Examples of service system optimisation. Application of simulation and Monte Carlo method in analysis and modelling of service systems. Examples from area of decision making and forecasting).

Laboratory work (use of adequate software).

prerequisite
There is no special conditions needed for course attending

learning resources
1. Bugaric, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011.

3. Bugaric, U.: Methodology for analysis of single position machines work, Foundation Andrejevic, Belgrade, 2003.

4. Software: QtsPlus 3.0 (Queuing theory software Plus).
5. Software: QSopt Version 1.0 (Linear programming problems).
6. Software: IOR Tutorial (Interactive Operations Research).
7. Software: MS – Project (Project management).
8. Personal computers.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 21
laboratory exercises: 9
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 9
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Petrić, J.: Operations Research (book 1 & 2), Savremena administracija, Belgrade, 1990.
Žiljak, V.: Computer simulation, Školska knjiga, Zagreb, 1982.
Clymer, J. R.: Systems analysis using simulation and Markov models, Prentice-Hall International Inc., 1990.
Churchman, C. W., Ackoff, R. L., Arnoff, E. L.: Introduction to Operations research, John Willey & Sons Inc., 1957.
Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.

Organization Design

ID: MSc-0574
responsible/holder professor: Spasojević-Brkić K. Vesna
teaching professor/s: Spasojević-Brkić K. Vesna
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to define the interdependence of the elements of organizational structure and processes so that in a given or anticipated situation organizationaly shaped organizational system (enterprise or its parts) achieves the persued objectives and goals.

learning outcomes
Through this course students acquire knowledge and skills in the fields of acquisition of theoretical and practical knowledge in the field of intentional and controlled development and changes in the organization to improve efficiency and effectiveness, and working conditions in the organization, alignment of organizational and technical / technological factors and changing of organizational culture and climate and setting the optimal model organization with respect to the objectives and available resources.By the end of the Organisation Design course student will be able to:

-tackle an organisation design project

-sequence and approach the design effectively

-apply various tools and techniques to make good organisation

-design decisions

-control the consequences and risks of design changes

-recognize design project blockers and challenges and

-address design project blockers and challenges.

theoretical teaching
Basic concepts of the design of organizations. Elements of organizational theory. Development of organizational theory. The concepts of organizational design. Directions of the past development of organizational theory. Situational model. Mintzberg`s model. Wilson`s model.Inkson`s model. Lawrence & Lorshov`s model. Frieblander`s model. Denning-Brown`s model. HPI model. Managerial grid model. Grainer`s model. Experience of local authors in designing the organization.Empirical organizational, technical, technological and cultural changes in organizational systems and its relation to performances.

practical teaching
Data collection about the business and production operations relevant factors in real conditions. The analysis of situational factors (environment, size, age and type of company). Analysis of strategic variables (growth and development strategies). Analysis of structural factors (technology 'type of production and organizational structure). Analysis of behavioral variables (organizational culture and climate). The analysis of business performances (development, operational and financial performance of companies). The proposal of new macro and micro organizational structure of the company. Check the proposed solution of the organizational structure OrgCon software package.

prerequisite
Students need to enroll 9th semester.

learning resources

1. Spasojevic Brkic V., Contingency theory and Quality Management, Faculty of Mechanical Engineering, Belgrade, 2009.

2. Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management of production, Faculty of Mechanical Engineering,Belgrade. 1996.

3.Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes,Faculty of Mechanical Engineering, Belgrade, 1996.

4.Cvijanović J., Designing Organizations, Institute of Economics, 1992.

5. Van de Ven A, Ferry D. Measuring and Assessing Organizations, John Wiley & Sons, New York, 2000.

6. Handout

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 3
laboratory exercises: 0
calculation tasks: 6
seminar works: 0
project design: 20
consultations: 1
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 1
check and assessment of projects: 5
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 35
final exam: 35
requirements to take the exam (number of points): 30

references

1. Spasojevic Brkic V., Contingency theory and Quality Management, Faculty of Mechanical Engineering, Belgrade, 2009.
2. Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management of production, Faculty of Mechanical Engineering,Belgrade. 1996.

3.Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes,Faculty of Mechanical Engineering, Belgrade, 1996.
4.Cvijanović J., Designing Organizations, Institute of Economics, 1992.
5. Van de Ven A., Ferry D., MEASURING AND ASSESSING ORGANIZATIONS, John Wiley & Sons, New York, 2000.

Production and Operations Management 2

ID: MSc-0413
responsible/holder professor: Milanović D. Dragan
teaching professor/s: Milanović D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
Studying the management process of business-production system in its interaction with the environment.Identification of problems in business-production systems and the process of solving them, with implementation procedure. Investigation and design of production macro and micro organizational structure. Management of business-production system and provision of all resources necessary for production normal operation.

learning outcomes
Upon the successful completion of this course, students should be able to:

- discuss the problems of business-production planning, organization and management,

- integrate subsystems into a functional whole,

- select the methods and techniques for problem solving,

- apply the methods and techniques for business-production problem solving,

- solve the problems of business-production management,

- evaluate and cooperate in solution implementation.

theoretical teaching
Complex optimization of business-production systems in thier interaction with the environment. Classification of business-production systems by the character of the technological process. Types of production organizational structure. Methods and techniques for scanning the current state of engineering-technological basics of production. Business-production problems and the process of solving them, with implementation procedure. Organizational structure of production and accessory units, operation and operational relations with organizational unit. Time management as an irretrievable resource, production cycle and delivery terms, flow coefficient, internal reserves and possibility of utilizing them. Design of macro, micro and intra organizational structure. Static and dynamic aspect with contents of jobs per organizational unit. Cybernetic model design for direct organization of production preparation and provision of all resources needed for normal operation of all work places. Methods and techniques of work place scanning.

practical teaching
Exercises are realized through project task in the enterprise. Project task should establish the most important organizational problems in an enterprise and propose how to solve them in order to improve organizational level in general and rationalize business operations and production. The design of jobs at work place is stressed. Job description, work conditions, job classification and work place matrix. Students are supposed to make concrete proposal for rationalization and improvement of operation of certain organizational wholes in business-production system by applying contemporary methods and techniques of industrial management.

prerequisite
Production and Operations Management 1 (not obligatory); semester certified.

learning resources

The enterprise where the project is to be realized, so that students get familiarized with realistic conditions of production, scan the current state-of-art and collect documentation. The Chair allows students to use equipment for scanning work conditions at work place. Use of additional literature is recommendable, depending on the project theme.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 30

references

V.Bulat: Organization of production, FME, Belgrade, 1999 /In Serbian/

T.Jovanovic, D.D.Milanovic, V.Spasojevic: Contemporary organization of production management,FME,Belgrade, 1996 /In Serbian/

T.Jovanovic, D.D.Milanovic, Z.Veljkovic: Collection of tasks in quantitative methods, FME, Belgrade, 1996 /In Serbian/

Quality improvement in production processes - Lean Six Sigma

ID: MSc-1249
responsible/holder professor: Veljković A. Zorica
teaching professor/s: Veljković A. Zorica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: industrial engineering

goals
Main subject goal is introduction to modern approaches and methods for efficiency and quality improvements in production processes using Lean production and Six Sigma approaches, i.e. Lean Six Sigma.

learning outcomes
At the end of the course students will be able to:

1. Apply Lean methods in production processes.

2. Apply Six Sigma methodologies.

3. Develop Lean six sigma production principles.

4. Construct and interpret process control charts .

5. Conduct traditional Design of Experiments.

6. Conduct Taguchi's experimental design techniques with according post analysis of experimental results in order to obtain best conclusions.

7. Apply TRIZ methodology.

theoretical teaching
Elemental concepts of Lean Six Sigma production:

1. DMAIC approach DO-MEASURE-ANALYZE-IMPROVE-CONTROL.

2. Implementation of Six Sigma in company by using champions, black, green, yellow and white belts.

3. Principles of x, s, R, p, c and U control charts, Design of experiments, Taguchi's approach and TRIZ methodology.

4. Basic of Lean production as an systematic methodology for waste elimination resulting with same or better productivity.

5. Relation and use of synergy between Lean production and Six Sigma.

6. Connection between Lean Six Sigma and Supply Chain Management.

practical teaching
1. Construction and interpretation of x, s and R control charts as well as p, c and U control charts.

2. Full and fractional factorial designs, design, experimentation, analysis and application of regression analysis.

3. Conducting experimentation using Taguchi's orthogonal arrays, linear graphs and triangular tables. Analysis of experimental results. Post analysis of experimental results by obtaining optimal experimental results using first and second errors, pooled error methods, S/N ratios and contribution ratio.

4. Practical application of TRIZ methodology

prerequisite
Prior knowledge of basic statistical methods.

learning resources
Handouts, examples, and literature for project realization.

number of hours: 30

active teaching (theoretical): 10
lectures: 10
elaboration and examples (revision): 0

active teaching (practical): 15
auditory exercises: 2
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 1

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 60
final exam: 30
requirements to take the exam (number of points): 31

references
Hendouts
Matherials from various books.

Risk management in Terotechnology

ID: MSc-0513
responsible/holder professor: Spasojević-Brkić K. Vesna
teaching professor/s: Spasojević-Brkić K. Vesna
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to apply maintenance systems based on risk management, due to knowledge in the identification, analysis, risk assessment and decision-making on the basis of these facts.

learning outcomes
Student after completing the course is able to: a) recognize /describe core systems, methods and strategies of terotechnology procedures b) applies terotechnology method based on risk, c) applies models RIMAP (Risk Inspection Maintenance Procedures) d) applies RCM models (Models for reliability based maintenance) in practice, and e) elect / propose appropriate solutions for the mitigation of risk. Upon successful completion of this course, students are able to choose the appropriate method, collect the data source required for the implementation of certain methods of risk management, conduct methodological procedure, conduct specific methods of processing results, critically consider and make decisions on the mitigation of risk depending on the results.

theoretical teaching
Introduction to terotechnology. Terotechnological procedures, operations and technologies. Aims and objectives of terotechnological activities. The principles of maintenance. Maintenance policy. Maintenance systems. The organizational structure of maintenance function. Maintenance methods and strategies. Maintenance methods based on risk. Maintaining the reliability - Reliability Centered Manintenance - RCM. Qualitative risk assessment. Risk-based Inspection - RBI. The concept of risk-based maintenance - RBIM. Risk Based Life Cycle Management of technical resources - RBLM. Based management rizoku - RBM. Maintenance procedures based on risk - RIMAP. Risk management tools. Risk assesment at workplaces and in environment. Application of risk management in national industrial practice.

practical teaching
Collection and systematization of data collected in companies. Evaluation of data on individual risks. Preliminary risk matrix. Calculation of individual riskc. Risk matrix. Preliminary evaluation of the possible scenarios of origin effects. Risk tools application. Detailed analysis of one or more of the selected scenarios, including probability analysis to achieve them. Detailed technical analysis of possible consequences of different scenarios. The overall analysis of possible consequences and analysis in terms of insurance and reinsurance.

prerequisite
Enrolled semester.

learning resources
1. Klarin M., Ivanovic G., Stanojevic P., Raicevic R. , Principles of Terotechnological Procedures, Faculty of Mechanical Engineering, Belgrade, 1994.

2. Smith D., Reliability, Maintainability and Risk - Practical methods for engineers, Elsevier Butterworth-Heinemann, Oxford, 2005.

3. Zio E., AN INTRODUCTION TO THE BASICS OF RELIABITY and RISK ANALYSIS, World Scientific Publishing Co., 2007.

4.Handout

number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 35
auditory exercises: 3
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 31
consultations: 1
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 10
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 25
final exam: 35
requirements to take the exam (number of points): 30

references

1. Klarin M., Ivanovic G., Stanojevic P., Raicevic R. , Principles of Terotechnological Procedures, Faculty of Mechanical Engineering, Belgrade, 1994.
2. Smith D., Reliability, Maintainability and Risk - Practical methods for engineers, Elsevier Butterworth-Heinemann, Oxford, 2005.
3. Zio E., AN INTRODUCTION TO THE BASICS OF RELIABITY and RISK ANALYSIS, World Scientific Publishing Co., 2007.

Skill Praxis M - IIE

ID: MSc-1250
responsible/holder professor: Misita Ž. Mirjana
teaching professor/s: Misita Ž. Mirjana, Spasojević-Brkić K. Vesna
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: project design
parent department: industrial engineering

goals
The aim of the course is improvement of the practical knowledge acquired on master studies courses through familiarizing students with the environment in which they will develop professional career and the recognition of the basic functions of the business system in the field of industrial engineering, as well as the role and tasks of mechanical / industrial engineers in such a business system.

learning outcomes
This course attendance enables the following:

- Student recognizes the organization and functioning of the environment in which they will apply the acquired knowledge in their future professional career, based on the information / data collected in the field.

- Student connects the knowledge acquired in other courses.

- Student identifies and critically examines models of organization and flow of business information.

- Student recognizes the basic processes in the design, production, maintenance, inventory management, quality and safety and health at work, in the context of his future professional competencies and critically analyze them.

- Student establishes the personal contacts and friendships that will be able to use during the study or when entering into future employment.

Upon completion of the course, students have practical knowledge and skills in the field of business organization and sustainable development of enterprises.

theoretical teaching
The theoretical knowledge acquired during studies at the Faculty of Mechanical Engineering is used.

practical teaching
Company visits and analysis based on real data collected in the fields:

Topic 1.: The history and the activity in which the practice is carried out.
Topic 2.: The layout of the company
Topic 3.: Organizational chart of the company
Topic 4.: Staffing structure
Theme 5.: Sales and procurement services
Topic 6.: Development sector (if any)
Topic 7.: Production planning sector
Theme 8.: The manufacturing sector - Capacities and production cycle
Topic 9.: Sector / Subsector of Quality Management
Topic 10.: Storage and transport
Topic 11: Maintenance management systems, using the methods of industrial engineering.

After completion of practical training, students must make a report that will defend to the responsible teacher.

prerequisite
Enrolled semester

learning resources
Data from pilot enterprises: documents, reports, databases, e-data.

Methods and techniques of industrial engineering described in learning resources:

1. Bulat V., Organization of production, Faculty of Mechanical Engineering, Belgrade, 1999.(in Serbian)

2. Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)

3. Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)

4. Tersine J.R., Production/Operations Management: Concepts, Structure and Analysis, Appleton & Lange, New York, 2005.

5. Sources collected in the companies

number of hours: 90

active teaching (theoretical): 5
lectures: 0
elaboration and examples (revision): 5

active teaching (practical): 80
auditory exercises: 0
laboratory exercises: 35
calculation tasks: 0
seminar works: 0
project design: 45
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 50
final exam: 50
requirements to take the exam (number of points): 30

references

Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
Bulat V., Organization of production, Faculty of Mechanical Engineering, Belgrade, 1999.(in Serbian)
Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
Tersine J.R., Production/Operations Management: Concepts, Structure and Analysis, Appleton & Lange, New York, 2005.

Techno-economic analysis and project management

ID: MSc-1248
responsible/holder professor: Bugarić S. Uglješa
teaching professor/s: Bugarić S. Uglješa
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: industrial engineering

goals
Students acquaintance with the goals of techno-economic analysis and the goals, processes and stages of project management. Acquaintance and mastering with modern methods, techniques, tools and areas of knowledge necessary for successful project management.

learning outcomes
Upon completion of the course syllabus students will be able to:

• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,
• Understand the concept of project management methodology and project management processes,
• Apply techno-economic analysis tools and techniques for project rentability,
• Develops a WBS structural diagram in order to define the scope of the project,
• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,
• Explains the importance of managing project costs,
• Explain quality control methods and techniques,
• Apply tools and techniques to support human resource management, risk management and procurement on the project,
• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,
• Apply adequate software in project management.

theoretical teaching
Definition and concept of the project. Classification and basic characteristics of projects. The concept of project management. Techno-economic analysis (static and dynamic measures of project profitability assessment). Organizational structures for project management. Participants in project implementation. Project life cycle. Project Management Processes (Group of processes for: project initiation, project planning, project execution, project monitoring and control, project completion). Project integration management. Project Scope Management. Project time management. Project Cost Management, Project Quality Management. Human resource management. Project communication management. Project risk management. Procurement management for the project. Introduction to basics and navigation in SAP solutions based on SAP ERP.

practical teaching
Determination of payback period, determination of present and future value of money, determination of net present value and profitability index. Network diagram structure analysis. Time analysis by the CPM method. Time analysis by PERT method. Determination of project completion probabilities and project costs using analytical methods and simulation. Project cost analysis and monitoring. Determination of risk in project realization. Working in specialized software packages (MS - Project, Exercises & Case Study - SAP module PS - Project Management).

prerequisite
None

learning resources

1. Bugaric, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2019.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011.

3. PMBOK - guide, Project management institute, 4th edition, FTN, Novi Sad, 2010. (in Serbian).

4. Software: SAP ERP.

5. Software: MS Office.

6. Software: MS – Project (Project management).

7. Personal computers.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 0
consultations: 0
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Jovanović P., Upravljanje projektom, FON, Beograd, 2006.
Kerzner H: “Project Management”, VIII издање, John Wiley & Sons, New Jersey, 2003.

INFORMATION TECHNOLOGIES

Algorithms and Data Structures

ID: MSc-0390
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: information technologies

goals
• Basic facts of algorithm theory.

• Abstract data type and basic implementation.

• Data structures in mechanical engineering.

• Using standard algorithms in solving simple problems in mechanical engineering.

learning outcomes
After successful completion of the program provided for in this case the student can:

• To find data structure to solve the problem.

• Use data structures and standard algorithms in solving simple problems in mechanical engineering.

• To find suboptimal algorithm to solve smple problems in mechanical engineering.

• To use standard algorithms to solve complex problems in mechanical engineering.

theoretical teaching
Basic facts about algorithms. Basic facts about abstract data type. Array. Lists. Buffers. Stack. Queue. Trees. Binary tree. Binary hip. Set. Hash. Dictionary. Varies sorting and searching algorithms with apply in mechanical engineering. Hanoi towers. Quick sorting and searching. Big numbers. Polygon triangulation. Flag problem. Optimal and suboptimal salesman problem. N-Queens problem. Stable marriage problem.

practical teaching
Workshops with basic examples.

prerequisite
Knowledge of C/C++ languages. Basic knowledge of program design methodology. Fundamentals of software engineering.

learning resources
The necessary software is under the GNU license - free of charge. In LINUX, C/C++ is immediately available. If you use another operating system, C/C++ compiler can be downloaded from the appropriate Web site (see URL).

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 13
calculation tasks: 0
seminar works: 15

project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 15
final exam: 30
requirements to take the exam (number of points): 35

references

C/C++

ID: MSc-0508
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran, Lazović M. Goran, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: information technologies

goals

• Introduce to C/C++; Structure of C/C++ and usability.

• Simple problems in mechanical engineering using C/C++.

• Art of pointers.

• Saving acquisition data in files, use that files and discussion results.

learning outcomes

After successful completion of the program provided for in this case the student can:

• Programing simple programs in C/C++ to solve problems in mechanical engineering.

• Use basic patterns in C/C++.

• Use pointers and simple data structures.

• Solve simple mechanical engineering problems with acquisition data in files.

theoretical teaching

Basic types. Constants. Operators and priority of operators. Blocks. If statement. Cycles. GOTO, BREAK and EXIT statements. Domain rules and variable declaration. Statical and registar variables. Definition and declaration of functions. Initialisation and recursion. Structures and fields. CHAR and Strings. Basic facts about pointers. Arrays and pointers. Adress aritmetic based on pointers. Command line arguments. Pointers to functions. Standard streams. Files and buffers. Some rules in using memory.

practical teaching

Workshops with basic examples in C/C++.

prerequisite

Knowledge of Programming, Computer tools, Numerical methods, Mathematics 1, Mathematics 2.

learning resources

The necessary software for this case under the GNU license - free of charge. If necessary use the Linux C/C++ is available to you immediately. If you use another operating system, C/C++ can be downloaded from the appropriate Web site (see URL) or the URL. To run the software necessary to possess enough simplest PC.

number of hours: 75

> **active teaching (theoretical):** 20
> lectures: 20
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 40
> auditory exercises: 8
> laboratory exercises: 17
> calculation tasks: 0
> seminar works: 8

project design: 4
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 4
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Computer graphics and virtual reality

ID: MSc-1304
responsible/holder professor: Vorotović S. Goran
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: information technologies

goals
Introduction to the study of the basic principles of computer graphics, elementary and complex transformations integrated in the radar space. Delimited and improved models of use of ready-made software solutions in the control of control graphic products in 2D and 3D models conceived on the radar platform. Integrating knowledge in the realm of virtual things through 2D and 3D elements' systems eliminates' flat 'screens and modern hardware solutions designed on library synergy and capable of having hardware.

learning outcomes
After successful completion of the program provided by this subject student can:

• apply the acquired knowledge in the scientific, technical and engineering applications of virtual reality technology,

• to design engineering software based on computer graphics,

• to integrate knowledge in the field of video game physicality.

theoretical teaching
Definitions of computer graphics. Analysis of raster and vector computer graphics. Record vector. The concept of pixels and address space. Elements of geometric transformations (scaling, translation, rotation of 2D and 3D objects in computer space). Graphic "engine". Analysis of usage of Open GL system and WEB GL system.

Overview of advanced engineering packages for real-time virtualization of models and phenomena.

Presentation of current hardware solutions for 3D object scans, transformation of physical into electrical and IT sizes in order to visualize objects and phenomena.

Fundamentals of Algorithm for Image and Sound Analysis.

Basics of virtual reality with elements of engineering problems analysis.

Fundamentals of Video Game Theory. Historical review. Analysis of sprites and transitions to modern engines.

practical teaching
It consists of auditory, laboratory exercises that monitor the content of the course.

prerequisite
Required: Basic computer culture based on PC usage, independent of operating system.

learning resources
-

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 21
calculation tasks: 0
seminar works: 7
project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Virtual Reality, Steven M. LaValle, Cambridge University Press, 2019
Virtual Reality Technology, Second Edition with CD-ROM Grigore C. Burdea, Philippe Coiffet ISBN: 0-471-36089-9 Wiley-IEEE Press; 2 edition (June, 2003)
Understanding Virtual Reality: Interface, Application, and Design R. Sherman, Alan Craig Series:Morgan Kaufmann series in computer graphics and geometric modeling Morgan Kaufmann; 1st edition

Computer Networks

ID: MSc-1303
responsible/holder professor: Vorotović S. Goran
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: information technologies

goals
Course objective:

• Introduction to the concept, standard tasks and operation of computer networks.

• Introduction to the protocol and other factors that control, manage and participate in creating a variety of processes and resources of computer networks and computers.

learning outcomes
The acquired knowledge allows students:

• to identify and suggest the type of computer network,

• to understand the problems that arise whendesigning computer networks,

• to create a project of computer network that includes a sugestion purchase of necessary equipment.

theoretical teaching
The basics of networking. The basic components of computer networks. Hardware. Software. The reasons for networking. The network environment.Use of Information. Passive network equipment. The active network equipment.Protocols. Computer interfaces. Standard computer networks. The division of computer networks. Grouping according to the capacity of computer networks for the transmission of data, the speed of transmission, according to a hierarchical or geographic area, according to the topology or logical and physical layout of nodes, as compared to nodes in a network, the architecture of computer networks and the access to computer networks.

The complexity and reference models.The role of the layers. OSI reference model. TSP / IP.

Physical layer. USB, FireWire, IrDA, Bluetooth, Ethernet, WiFi, ISDN, xDLS. Link layer. The division of link layer. Access Control (MAC), Logical Link Control (LLC). Flow control. Control error. Link layer protocols. Ethernet. ARP.Token Ring. FDDI.

Network layer. Internet Protocol (IP).Networks and network classes. CIDR. ICMP.IGMP.IPX. RARP. BOOTP. DHCP. IPv6.

Transport layer. TCP, UDP, SCTP, SPX, iSCSI.

Application layer. SSH. Remote Desktop. DNS. FTP. Electronic mail. SMB / CIFS. HTTP.

NTP. SNMP.Voice over IP. Instant Meassaging. Video conference. Operating systems in computer networks. Implementation of network support. Comparison and analysis of some features of contemporary operating systems. Security. Accessibility. Performance. Possible attacks and protect computer networks. Firewall. IDS and IPS systems.

practical teaching
It consists of auditory, laboratory exercises thatfollow the content of course.

prerequisite

Required: Basic computer culture based on the use of a PC, regardless of operating

systems.WEB design in mechanical engineering,Software Engineering.

learning resources

The necessary software for this case under the GNU license - free of charge.

• To run the necessary software is enough to havethe simplest PC.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 21
calculation tasks: 0
seminar works: 7
project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references

Birman, Kenneth. Reliable Distributed Systems: Technologies, Web Services and Applications. New York: Springer-Verlag, 2005.

Gray, J. and Reuter, A. Transaction Processing: Concepts and Techniques. San Mateo, CA: Morgan Kaufmann, 1993.

James F. Kurose, Keith W. Ross, Umrežavanje računara, Cet, Beograd, 2005.

de Andrade, R.; Hodel, K. N.; Justo, J. F.; Laganá, A. M.; Santos, M. M.; Gu, Z. (2018). "Analytical and Experimental Performance Evaluations of CAN-FD Bus". IEEE Access. 6: 21287 - 21295.

Data Exquisite in Mechanical Engineering

ID: MSc-0510
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: information technologies

goals
Course objective:

• Numerical and mathematical analysis capabilities for each measurement.

• Design and write programs for analyzing measurements.

• Comparison analysis of numerical data processing and analysis software.

• Implementation of PHP and JAVA Script.

learning outcomes
The acquired knowledge allows:

• That be entered professional do the measurements and determine the necessary and forward the required size,

• That the measurement is so mathematical, numerical and statistical analysis and then to be graphical and logical preparation for further analysis,

• That, using PHP or Java Script, or both, make software to perform accurate data processing which is a pre-determined mathematically.

theoretical teaching
BASIC THEORY OF SAMPLES. Population and simple sample with replacement and without returning. Sampling - the empirical distribution as a possible Code of Conduct of the population.

TREATMENT OF STATISTICAL BASIS

The concept of statistical meetings. Mean values of statistical assemblage. Dispersion. Models of the distribution. The trend in the study of statistics. Time series in the study of statistics. Statistical indicators in the study. Hypotheses and tests.

ARISING FROM PROBABILITY. The mathematical probability of an event. Addition theorem of probability. Multiplication theorem of probability. Permutations, combinations and variations of elements of one set.

REPETITORIA numerical methods. Some algebraic problems. Interpolation polynomials. Lagrange interpolation polynomials (Joseph-Louis Lagrange). Newton (Isaac Newton) interpolation polynomials. Numerical integration. Newton-Coates (Isaac Newton - Roger Cotes) formula. Simpson (Thomas Simpson) formula.

IMMEDIATE MEASUREMENT ACCURACY Equal and unequal. Determining the value of measured values. Determination of measurement error. Distribution law of random sizes.

INDIRECT MEASUREMENT ACCURACY OF EQUAL. Determining the average size of the errors of certain indirect measurement. Determining the size of the average error of certain indirect measurement of the same accuracy. The general case of indirect measurement of the system of equations equal accuracy.

INDIRECT MEASUREMENT ACCURACY unequal. Normal equations indirect measurements of unequal accuracy. Control in solving the normal equation of unequal accuracy.

CONDITIONAL MEASUREMENTS SIZE. The process of measuring the conditional correlations. The process of reducing the indirect measurements.

Basic Theory of Correlation. Two-dimensional distribution laws of random sizes.

practical teaching
It consists of auditory, laboratory exercises that accompany the course.

prerequisite
Required: Basic computer culture based on the use of a PC, regardless of operating sistema.Osnovno knowledge of mathematical logic.

learning resources
Audience is available licensed software owned by the faculty. Listeners freeware software is available.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 21
calculation tasks: 0
seminar works: 7
project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Č. Mitrovic, S. Radojevic, The Data Exquisite in Mechanical Engineering, a textbook (in preparation) Faculty of Mechanical Engineering, Belgrade

Designing software for mechanical engineers

ID: MSc-1148
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: information technologies

goals

• Prepare inputs for the engineering software based on standard calculations.

• Preparation of engineering calculations for effective programming and obtain efficient programs.

• Testing and verification of software engineering. Validation of software engineering.

• Use SQL to get information from databases.

• Use SQL for engineering decision making.

• Organization, normalization of data in the database.

• Privacy, data archiving. Issues of software licensing.

learning outcomes

After successful completion of the program provided for in this case the student can:

• Prepare a budget for programming.

• to assess the quality of information obtained from the input data that are processed program written for a defined budget.

• use the database for specific problems in mechanical engineering.

• use SQL as a generator of low-level information for software engineering.

theoretical teaching

1. Basic numerical methods in the calculations.

2. Designing software for selected numerical methods and calculations. Finding the zero function. Numerical differentiation and numerical integration.

3. Designing software for selected numerical methods and calculations. Numerical solution of partial differential equations and first order. Basic statistics.

4. Relational algebra, relations, and indexing. Basic SQL commands to create objects.

5. Basic SQL commands to update the object and relational operations.

7. Testing program. Validation of results and errors in calculation.

8. Software Licensing.

practical teaching

It consists of the auditory, laboratory exercises that accompany the course.

Case Studies. The commemoration of the database design, different tools.

Database-based storage of drawings, photographs and complex objects.

prerequisite

Database design. Software Engineering.C/C++

learning resources

The necessary software for this case under the GNU license - free of charge. If you use Linux you needed Python is readily available. If you use another operating system, Python can be downloaded from the appropriate Web site (see URL) or the URL. To run the software necessary to possess enough simplest PC.

number of hours: 75

> **active teaching (theoretical):** 20
> lectures: 20
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 40
> auditory exercises: 11
> laboratory exercises: 19
> calculation tasks: 0
> seminar works: 5
> project design: 2
> consultations: 0
> discussion and workshop: 3
> research: 0
>
> **knowledge checks:** 15
> check and assessment of calculation tasks: 0
> check and assessment of lab reports: 0
> check and assessment of seminar works: 7
> check and assessment of projects: 0
> colloquium, with assessment: 0
> test, with assessment: 3
> final exam: 5

assessment of knowledge (maximum number of points - 100)

> feedback during course study: 5
> test/colloquium: 35
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 30
> project design: 0
> final exam: 30
> requirements to take the exam (number of points): 35

references

Jery R. Hanly, Essential C++ for Engineers and Scientists, Addison Wesley, ISBN 0-201-74125- 3

Distributed Systems in Mechanical Engineering

ID: MSc-0522
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: information technologies

goals

- Introduction to the paradigm of distributing data
- Knowledge of basic protocols for the transfer and sharing of distributed data.
- Designing local area networks based on different technologies
- Introduction to multiprocessor distributed systems in the automotive and aircraft industry
- Introduction to algorithms that are typical of multi-processor distributed systems

learning outcomes

- to recognize the conditions for the formation of local area networks
- to allocate names to resources on the net
- to control and menage assigned resources
- to understand the multi-processor and redistribution of data among them

theoretical teaching

Local and remote computer network as a weak coupled systems. The concept of server and service provider Indoor network systems. Assignment of rights and names in the closed network systems. Application of these systems in the automotive and aircraft industry. Local area network-LAN Connect local area networks. The protocols in use. Bluetooth protocol for small local networks. Routing and ranges in routing. Recommendations in the formation of IEEE local computer networks and their links. IP protocol. Wireless local area networks. Use of multi-radio waves in the small computer networks. User control in a wireless network Multiprocessor systems. Algorithms for controlling the resources used in operating systems for multiprocessor hardware systems. The case studies specific to the automotive industry. Case studies characteristic of the civil and military aerospace industry.

practical teaching

It consists of auditory, laboratory exercises that accompany the course. We should particularly look at case studies in the auto industry and the aviation industry.

prerequisite

Required: Basic computer culture based on the use of a PC, regardless of operating system.

learning resources

- The necessary software for this case under the GNU license - free of charge.
- To run the necessary software is enough to have the simplest PC.

number of hours: 75

> **active teaching (theoretical):** 20
> lectures: 20
> elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 16
calculation tasks: 0
seminar works: 7
project design: 8
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 15
laboratory exercises: 5
calculation tasks: 0
seminar works: 15
project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references

Embedded systems and IoT in mechanical engineering

ID: MSc-1346
responsible/holder professor: Vorotović S. Goran
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: information technologies

goals
Acquisition of theoretical and practical knowledge in the field of embedded systems and Internet of Things.

learning outcomes
Students are trained for practical work with embedded systems in the Internet environment. Students have theoretical knowledge of Internet architecture and embedded systems.

theoretical teaching
1. History and reference models, ISO-OSI.
2. TCP-IP reference model.
3. Network hardware and software.
4. Protocols, HDLC, PPP.
5. Local area networks.
6. Routing algorithms.
7. Network layer, IP protocol.
8. Management protocols, ICMP, ARP, DHCP, RIP.
9. Transport level, TCP, UDP.
10. Application level, sockets, DNS, email, FTP, www, http.

practical teaching
It consists of auditory, laboratory exercises that monitor the content of the course.

prerequisite
Required: Basic computer culture based on PC usage, independent of operating system.

learning resources
-

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 21
calculation tasks: 0
seminar works: 7
project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
de Andrade, R.; Hodel, K. N.; Justo, J. F.; Laganá, A. M.; Santos, M. M.; Gu, Z. (2018). "Analytical and Experimental Performance Evaluations of CAN-FD Bus". IEEE Access. 6: 21287 - 21295.
James F. Kurose, Keith W. Ross, Umrežavanje računara, Cet, Beograd, 2005.

Gray, J. and Reuter, A. Transaction Processing: Concepts and Techniques. San Mateo, CA: Morgan Kaufmann, 1993.

Birman, Kenneth. Reliable Distributed Systems: Technologies, Web Services and Applications. New York: Springer-Verlag, 2005.
G. Vorotović at all: „Possibilities of BLOB and CLOB Integration Into the Core of IoT and Using the SQL Platform for Distributing a Large Amount of Data to HTML, JAVA, and PHP Plat.“; IGI Global 2017.

Information Technology Projects Evaluation

ID: MSc-0512
responsible/holder professor: Dondur J. Nikola
teaching professor/s: Dondur J. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: information technologies

goals
Understanding of the importance of the planning process, assessment and evaluation of projects in the field of information technologies. Getting to know different methodological approaches for analysis of IT/IS projects. Learning the sophisticated techniques of financial and economic analysis, as well as standard techniques for management of IT/IS projects. Learning the techniques and routines for identification and monetary quantification of hardly visible costs and effects implied in the implementation of IT/IS projects.

learning outcomes
After having attended the module, the student should be able to: identify the project idea, prepare a database with all costs and effects of IT/IS projects, calculate criteria for selection of project alternatives, acquire knowledge and practices for recognition of hardly visible costs and effects of IT/IS projects, organise networks of activities, flows of project resources with choice of optimal paths and minimum costs and assess uncertainty and risk of IT/IS projects.

theoretical teaching
Projects in the area of information technologies, planning and assessment of IT/IS projects, methods of assessment and evaluation of IT/IS projects, standard (classical) methods of commercial assessment of IT projects, standard methods of economic assessment of IT projects, possible application of standard methods on IT/IS projects - COMFAR,COSTTAB, quantification of financial and economic net effects of IT/IS projects, analysis of uncertainty and risks in planning – use of software packages RISK, RISKVIEW, BESTFIT, CRYSTAL BALL, assessment and evaluation of IT/IS projects, management of IT/IS projects – use of software packages MSPROJECT, PRIMAVERA

practical teaching
Practical teaching consists of auditory and laboratory exercises as integral part of the module content. Auditory exercises include simple demonstrations of theoretical materials presented through examples and accompanied by the explanations to each step

prerequisite
Required: Basic knowledge of computer science, economics and statistics. Preferred: attended modules on Databases, WEB Design.

learning resources
Softwares: EXCEL, MSPROJECT, RISKPROJECT, RISKFOREXCEL. Books: Economic Project Analysis, Information Technology Evaluation Methods and Management,

number of hours: 75

> **active teaching (theoretical):** 20
> lectures: 20
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 40
> auditory exercises: 9
> laboratory exercises: 15

calculation tasks: 0
seminar works: 16
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 55
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
David Potts:Project Planning and Analysis for Development,Rienner, London, 2002.

Methods of Optimization

ID: MSc-1404
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Bengin Č. Aleksandar, Bengin Č. Aleksandar, Bengin Č. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: information technologies

goals
The main goal of this course for the student is to give the necessary knowledge of:

• numerical analysis and optimization,

• understanding general principles of design optimization

• formulating the optimization problems and identify critical elements.

learning outcomes
After completing this course students are able to successfully apply the acquired theoretical and practical knowledge and are able to:

• Identify relevant optimization variables, define the set of functional constraints and limitations for the corresponding optimization model of a given mechanical system.

• Apply linear and non-linear numerical methods for solving the optimization problems and define the appropriate convergence criteria.

• Develop and implement computer programs in software packages Python / MATLAB for solving the set of optimization tasks.

• Analyze the results and check the validity of the proposed optimization models with respect to the change of input parameters.

• Apply the stochastic - heuristic methods and develop hybridized heuristic methods to determine the global solution of the optimization problems of complex mechanical systems.

• Develop new and apply existing numerical methods for solving complex optimization tasks, individually or as part of an appropriate team.

theoretical teaching
1. Introduction to Modeling and Optimum Design Process. Optimum design problem formulation.

A general mathematical model for optimization.

2. Graphical Optimization.Identification of feasible region. Use of MATLAB for graphical optimization.

3. Unconstrained Optimum Design Problems. Optimality conditions for functions of several variables.

4. Constrained optimum design problems. Necessary conditions: equality constraints.

Necessary conditions: inequality constraints - Karush-Kuhn-Tucker (KKT) conditions. Postoptimality analysis: physical meaning of Lagrange multipliers.

Engineering design examples with MATLAB.

5. Linear Programming. Problem definition. Standard LP format. Graphical solution. Characteristics of the solution. Optimum solution for LP problems.

6. Numerical Solution - the Simplex Method.

Basic Steps of the Simplex Method. Simplex Algorithm. Solution using MATLAB's optimization toolbox.

7. Nonlinear Programming. Problem formulation. Graphical solutions. Equality constrained problem. Inequality constrained optimization.

Basic ideas and algorithms for step size determination.

8. Numerical methods - The One-dimensional Problem.

Newton-Raphson method.

Bisection method.

Polynomial Approximation.

Golden section method.

Optimum design examples with MATLAB.

9. Numerical Methods for Unconstrained Optimization.

Numerical Methods - Nongradient methods.

Powell's method.

Numerical Methods-Gradient-Based Methods.

Conjugate Gradient (Fletcher-Reeves) Method.

Davidon-Fletcher- Powel (DFP) method.

10. Numerical Methods for Constrained optimization

Problem definition. Necessary conditions. Method of feasible directions.Gradient projection method.

Exterior penalty function method.

Optimum design examples with MATLAB.

practical teaching

Consists of the auditory and laboratory exercises.

Projects are main component of this course.

prerequisite

Knowledge of linear algebra and numerical mathematics. Computer programming in MATLAB.

Some knowledge of basic machine elements and mechanics.

learning resources

Computer Usage:

Students extensively use the computer and optimization toolbox using MATLAB program.

Handout.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 6
laboratory exercises: 21
calculation tasks: 0
seminar works: 7

project design: 3
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Jasbir S. Arora " Introduction to Optimum Design", Elsevier Academic Press
P. Venkataraman " Applied Optimization with Matlab Programming" John Wiley and sons, inc.
H. Eschenauer, J. Koski, A. Osyczka "Multicriteria Design Optimization", Springer-Verlag

Numerical Methods in Continuum Mechanics

ID: MSc-1149
responsible/holder professor: Bengin Č. Aleksandar
teaching professor/s: Bengin Č. Aleksandar, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: information technologies

goals
Introducing students with engineering simulations based on continuum mechanics. Understanding a well-defined problem as a unity of physical laws and additional conditions that define uniqueness and existence of a solution. Learning about the influence of the type of problem on the choice and type of additional conditions, as well as the choice of approximation to solve typical problems in continuum mechanic. Training students to independently develop computer programs for simulation of prototypical equations.

learning outcomes
By successfully adopting the program of the course, a student: acquires theoretical knowledge sufficient to recognize the type of the problem as well as the type and number of additional conditions necessary to completely and uniquely define the problem that is being simulated; recognizes basic approximation schemes of the typical problems; masters the principles and foundations of programming related to simulations of continuum; observes the structure of the simulation software that consists of pre-processing, simulation and visualization.

theoretical teaching
Introduction to engineering simulations, Analytic solutions of partial differential equations, Finite difference method, Parabollic partial differential equations, Non linear parabolic partial differential equations, Stability analysis, Elliptic partial differential equations, Conjugent gradient method, Multigrid method, Hiperbolic partial differential equations.

practical teaching
Practical training accompanies materials presented during theoretical lectures. In the beginning, students are registered and they familiarize with working in Linux operating system. After that, illustrative examples are completely presented starting wi

prerequisite
Without prerequisites.

learning resources
Linux cluster, GNU C/C++ compiler.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 0
> laboratory exercises: 20
> calculation tasks: 0
> seminar works: 5
> project design: 0
> consultations: 5

discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 15
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 55
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Lectures in electronic form.

Object oriented paradigm

ID: MSc-1402
responsible/holder professor: Vorotović S. Goran
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran, Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: information technologies

goals

• Introduction to OOP paradigm.

• Purposeful use of classes, objects, inheritance, encapsulates, methods and hiding.

• Basic knowledge of classes, derived classes, methods.

• Object-oriented methodology for designing data structures and applicable programs.

• Problems that are naturally solved using object-oriented design and programming methodology.

learning outcomes

With acquired knowledge student can:

• to recognize the conditions for using object-oriented design and programming methodology,

• to design simple user class and link them with the system classes,

• user to design simple methods and their use in system design methods,

• to use the programming languages C + + and Java.

theoretical teaching

Compilers, interpreters and machines. Weak and strong typed programming languages.

Object and class, relationship and real-life examples and techniques.

The natural definition of class, subclass, supclass. The term instance - the object.

Fundamentals of programming language C + +. The differences between the programming languages C and C + +. Defining classes in C + +. Application of operations and creating objects. Object-oriented design data, operations, and problems in the programming and implementation. The life span of the object. The basics of Java programming. The differences between the programming languages C + + and Java. Defining the class and subclass supclass in programming languages C + + and Java. Inheritance in C + + and Java, the advantages and disadvantages. Overloading of operators and create threads and streamline, as well as specific structures in Java. Problem encapsulate objects and classes. The advantages and disadvantages.

practical teaching

It consists of auditory, laboratory exercises that accompany the course.

The commemoration of the programming language PHP programming.

Basic examples of the programming language C + + and Java.

prerequisite

With the knowledge C language. Basic knowledge of design methodology. Fundamentals of software engineering.

learning resources

The necessary software for this case under the GNU license - free of charge. If necessary use a Linux C + + and JAVA will immediately available. If you use another operating system C + + can be downloaded from the appropriate Web site (see URL) or the URL. To run the software necessary to possess enough simplest PC.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 11
laboratory exercises: 19
calculation tasks: 0
seminar works: 5
project design: 2
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Programmable Control Systems

ID: MSc-1403
responsible/holder professor: Vorotović S. Goran
teaching professor/s: Bengin Č. Aleksandar, Vorotović S. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: information technologies

goals
The objective of this course is that students: acquire necessary knowledge in design, programming and implementation of programmable control systems in industry and contemporary manufacturing; master the skills for practical problem solving in industrial control using computer, information and control technologies and appropriate scientific methods.

learning outcomes
After successfully completing this course, the students should be capable to:

- Analyze social, economic, production and other effects of programmable control systems;

- Integrate knowledge in related subjects and implement them in programmable control systems design;

- Analyze and synthesize combinational automata;

- Synthesize sequential automata;

- Carry out electro-pneumatic realization of combinational and sequential automata;

- Program programmable logic controllers.

theoretical teaching
1. Programmable and computer control systems in automation: robot controllers, programmable controllers, controllers in programmable automation and computers.

2. Number systems and codes: positional number systems (decimal, binary, octal, hexadecimal); conversion of numbers between positional number systems; binary coded decimal; Gray code; alphanumerical codes.

3. Switching algebra: axioms of Boolean algebra; elementary operations of switching algebra; theorems of switching algebra; logic functions; canonical forms of logic functions (sum of minterms and product of maxterms); minimization of logic functions.

4. Technologies and components: sensors and actuators.

5. Combinational and sequential automata: definition, models, synthesis and analysis; Electropneumatic realization.

6. Programmable logic controllers: functions, hardware, software, input-output modules; programming languages and programming.

practical teaching
Auditory exercises: examples in automation design, control system analysis and synthesis, programmable controllers programming, and control scheme design.

prerequisite
None.

learning resources
IT Laboratory - wind tunnel.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 22
laboratory exercises: 0
calculation tasks: 0
seminar works: 8
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 20
laboratory exercises: 10
calculation tasks: 0
seminar works: 15
project design: 0
final exam: 50
requirements to take the exam (number of points): 30

references

Skill Praxis M - MIT

ID: MSc-1232
responsible/holder professor: Mitrović B. Časlav
teaching professor/s: Mitrović B. Časlav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: project design
parent department: information technologies

goals
To provide students with practical experience of staying in an environment in which the student will realize his future career. Identifying the basic functions information system in the field of design, development and production software, as well as roles and tasks of mechanical engineering of information technology in such business system.

learning outcomes
Training students to apply previously acquired theoretical and practical engineering and scientific knowledge of information technology to solve specific practical engineering problems in the selected companies or Institutions.

Activities to introduce students to selected companies or institutions, way of doing business, management and the place and role of IT engineers in their organizational structures.

theoretical teaching
MIT provides students with practical training by working with reputable companies and scientific research institutions of Serbia in the IT sector.

Practical form for each candidate separately, in agreement with the management companies or research institutions in which pursuing their profession, and in accordance with the development of new information technologies from which the student has previously acquired theoretical knowledge.

practical teaching
Practical work consists of student involvement in the process of the enterprise or research institutions, consulting and writing diary professional practice in which a student describes the activities and operations that is performed during the profession.

prerequisite
Required: Basic IT knowledge. Prior knowledge acquired in previous modules MIT cources listened.

learning resources
Lectures for MIT courses modules that can be downloaded from the FTP server module MIT: ftp://mit.mas.bg.ac.rs

number of hours: 90

active teaching (theoretical): 0
lectures: 0
elaboration and examples (revision): 0

active teaching (practical): 80
auditory exercises: 0
laboratory exercises: 80
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0

discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 10

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 60
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

INTERNAL COMBUSTION ENGINES

Ecology of Mobile Power Sources

ID: MSc-1024
responsible/holder professor: Knežević M. Dragan
teaching professor/s: Knežević M. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written+oral
parent department: internal combustion engines

goals
Acquiring basic knowledge of IC engine's influence on environment. Knowledge of pollutants origin in exhaust of IC engines and the ways of their reduction. Understanding of legal obligations and emission standards.

Pollution by hybrid and electric vehicles and their impact on the natural environment. Vehicles with zero exhaust emissions.

Acquiring basic knowledge of noise sources in IC engines and the methods of noise reduction.

Construction of an after-treatment system for exhaust gases.

learning outcomes
Understanding the influence of human activities on environment, especially of harmful ones. Knowledge of pollutants formation chemistry, the greenhouse gases effects on global climate change, and noise of IC engines. Ability to apply solutions for pollutants and noise reduction.

theoretical teaching
1. Impact of IC engines on environment - general view (pollutants in exhaust, emission of greenhouse gases, engine noise). 2. Chemistry of pollutants formation in exhaust emissions of spark-ignition and compression-ignition engines, and the ways of their reduction. 3. Law regulations of the engine exhaust pollutants emissions. 4. NEDC (New European Driving Cycle) test and new WLTP (Wordwide Harmonised Light Vehicle Test Procedure)test. The purpose of the WLTP lab test and the way it works. 5. Greenhouse gases emission and their impact on global warming. 6. Engine noise, sources, standards, ways of reduction. 7. Engine exhaust emission regulations. 8. Alternative power system emission and electric-powered vehicles emission. 9.Impact of engine design on pollutants emissions and engine noise. 10.Construction solutions for the after-treatment system of exhaust gases, the principle of operation and type.

practical teaching
a) Classroom sessions: 1. Numerical examples. 2. Review and analysis of in-cylinder and after-treatment solutions for pollutant exhaust gases reduction: EGR, three-way catalyst, catalyst after-treatment of diesel engine exhaust emission. 3. Review and analysis of engine design solutions for engine noise reduction.

b) Laboratory sessions: 1. Measurements of engine exhaust emissions with and without EGR.

prerequisite
Mandatory: passed exam Engine Working Processes.

learning resources
Handouts (PDF files); Instructions to carry out lab session and prepare and write report; numerical assignments examples; test bed with IC engine, measurement equipment and software for data acquisition, exhaust gases analizers.

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 11
laboratory exercises: 3
calculation tasks: 2
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 30

references
Sher, E. (Ed.): Handbook of air pollution from internal combustion engines. Academic Press, San Diego, 1998. ISBN 0-12-639855-0. (na engleskom)
Heywood J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, New York, 1988. ISBN 0-07-028637-X. (na engleskom)
Gruden, D.: Umweltschutz in der Automobilindustrie. Vieweg+Teubner, Wiesbaden, 2008. ISBN 978-3-8348-0404-4. (na nemačkom)

IC Engine Design 1

ID: MSc-1087
responsible/holder professor: Knežević M. Dragan
teaching professor/s: Knežević M. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals

The aims of the course are to provide theoretical and practical study about engine dynamics,vibrations and design of engine parts. Through the evaluation of engine kinematics, dynamics and engine parts mechanical load and stress students acquires a sense for design of engine parts and complete engine. Basic knowledge about 3D modeling of engine parts and stress calculation using FEM is also provided and enable modern approach to engine design.

learning outcomes

The merger of theoretical knowledge of mechanics, basics of strength of constructions and machine elements and its applications on engine design. Training students for engine parts and systems design, modeling and calculation. The acquisition of basic theoretical and practical knowledge required for complete engine designing.

theoretical teaching

1. Kinematics of piston mechanism. Dynamics of piston mechanism and transfer of the forces through engine mechanism. Variations of engine torque and crankshaft rotational speed. Balancing of inertia forces of single cylinder engine and inertia forces and its moments of multi cylinder engines. 2. The role, design, choice of materials and evaluation of mechanical stress of engine piston group elements. Design, choice of materials and evaluation of mechanical stress of engine connecting rod. Design, choice of materials and evaluation of mechanical stress of engine crankshaft and crankshaft bearing. 3. Problem of engine vibrations; vibration on the engine mounts; torsion vibrations of engine crankshaft.

practical teaching

1. Forces of engine piston mechanism; crankshaft tangential force and the variations of engine torque and crankshaft rotational speed, the role and calculation of engine flywheel; instructions for engine kinematics and dynamics calculation. 2. Examples of engine parts design and thermal and mechanical stress calculation; instructions for mechanical calculation of piston group, connecting rod and crankshaft. 3. The application of 3-D modeling in engine parts design;

prerequisite

No prerequisites required.

learning resources

1. M.C. Živković: Internal combustion engines, part 2. Engine design 1, Kinematics and dynamics of piston mechanism. Faculty of Mech. Eng., Belgrade, 1983.

2. M.C. Živković, R. Trifunović: Internal combustion engines, part 2. Engine design 2, Design and calculation of engine basic elements, Faculty of Mech. Eng., Belgrade, 1985.

3. M.Tomić: Engine design 1-Handouts, available in PDF format in IC engines department.

4. Sections of the engines. Various parts of the engines. Complete engines prepared for disassembling and assembling.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 16
laboratory exercises: 0
calculation tasks: 4
seminar works: 0
project design: 7
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 30

references
M.C. Živković: Internal combustion engines, part 2. Engine design 1, Kinematics and dynamics of piston mechanism. Faculty of Mech. Eng., Belgrade, 1983
M.C. Živković, R. Trifunović: Internal combustion engines, part 2. Engine design
Köhler, E., Flierl, R: Verbrennungsmotoren: Motormechanik, Berechnung und Auslegung des Hubkolbenmotors
Van Basshuysen, R., Schafer, F. (Editors): Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, Warrendale, 2004. ISBN 978-0- 7680-1139-5
Challen, B., Baranescu, R. (Editors): Diesel Engine Reference Book - 2nd ed., Butterworth- Heinemann, Woburn, 1999. ISBN 0-7506-2176-1.

IC Engine Design 2

ID: MSc-1089
responsible/holder professor: Knežević M. Dragan
teaching professor/s: Knežević M. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: internal combustion engines

goals
Acquiring new knowledge on role and design features of IC Engine Auxiliary systems - engine cooling & lubricating systems and starting devices. Developing skills to design and calculate working parameters of IC Engine Auxiliary Systems. Practical application and broadening knowledge in the field of Heat Transfer, Machine Design, Tribology and Engineering Materials.

Torsional oscillations of the engine crankshaft. The formation of torsional oscillations, the risk of torsional oscillations, the ways of suppression of torsional oscillations, construction of torsional silencers.

Specific design of two-stroke engines.

learning outcomes
Understanding the Design of complex machines and Devices. Recognition and understanding of the importance of subsystems for proper functioning of the system as whole. Understanding the design principles and role of Cooling System, Heat transfer, Lubrication System and Starter System.

Understanding of the torsion silencer construction.

Capabilities to design and calculate vital components of IC Engine Auxiliary Systems.

theoretical teaching
IC Engine Cooling System: The role and Engine Thermal Load Issues;Liquid & Air Cooling Systems: Design and calculation; IC Engine Lubrication System: Design & Disposition; Lubricant Characteristics: Engine Requirements; Stribeck's Diagram; Lubrication Pump - Design & Calculation, Lubricant Filtration; IC Engine Starting Devices; Work required for Engine starting and running; Engine starting Devices Design Issues; Pneumatic Starters; Engine Crankshaft Rotation Reversing Devices - Design & Application Issues.

practical teaching
1. IC Engine Cooling System Design & Calculation - Waste Heat removed through Cooling System, Liquid & Air Cooling System Calculation Examples; 2. Engine Lubrication System Calculation Examples, Waste Heat removed through Lubrication System, Circulating Pump design and calculation;

Project Task: Design and calculation of Cooling/Lubricating System

prerequisite
Passed exam on course "IC Engines Processes"

learning resources
1. M.Tomić, M. Cvetić: Extracts from lectures (handouts) in digital form

2. D. Knežević: Extracts from lectures (handouts) in digital form

3. D. Knežević: Liquid & Air Cooling System Calculation Examples & Instructions in digial form

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 0
calculation tasks: 8
seminar works: 0
project design: 10
consultations: 2
discussion and workshop: 2
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 8
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 30

references

Challen, B., Baranescu, R. (Editors): Diesel Engine Reference Book - 2nd ed., Butterworth-Heinemann, Woburn, 1999. ISBN 0-7506-2176-1.

Van Basshuysen, R., Schafer, F. (Editors): Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, Warrendale, 2004. ISBN 978-0-7680-1139-5.

John Heywood: Internal Combustion Engine Fundamentals, Mc Graw-Hill, 1988, ISBN-13: 978-0070286375

IC Engine Testing

ID: MSc-0860
responsible/holder professor: Miljić L. Nenad
teaching professor/s: Miljić L. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals
To cover the basic knowledge of experimental work in the field of IC Engines. Broadening of measuring techniques knowledge, used in engineering, through acquaintance with specific measuring equipment, devices and software tools used for IC engine testing. Developing of skills required for developing of IC engines test facilities, choice of adequate measuring equipment, devices and auxiliaries for funding IC engine test bench. Developing of skills required for planning, organization and conducting an IC Engine testing.

learning outcomes
Practical knowledge in IC engine testing procedures, operations and data analysis. Ability in solving and analysis of practical engineering tasks related to IC engine testing and IC engine test measuring equipment and facilities

theoretical teaching
Measurement of: Torques and forces; rotational speed and acceleration; gas and fuel mass and volumetric flow (with anemometry); temperatures and pressures; IC engine indicating techniques and measurement equipment; IC Engine exhaust analysis; Engine dynamometers; Fundamentals of IC Engines test benches design; IC engine testing standards, procedures and operations

practical teaching
Measurement errors and uncertainty (examples with calculation tasks); Introduction to Labview (NI) measurement and programming environment; Calibration of measurement chains; Preparation for laboratory tasks (description of measuring equipment and chains used, task instructions):

Getting acquaintance with the Labview environment and its usage in IC engine testing tasks; Calibration of specific transducer measurement chain (torque, pressure, temperature,...); IC Engine in cylinder pressure indicating; Measurements on engine test bench - gathering data for BSFC characteristics map; Determining the energy balance of an ICE

prerequisite
Passed exam on course “IC engine working processes”

learning resources
-Živković, M.C, Trifunović, R.: IC Engine Testing (on Serbian), FME Belgrade

- Lecture Handouts, Lab Exercises Instructions, Calculus examples (pdf)

- Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)

- DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 14
calculation tasks: 4
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 6
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 20
laboratory exercises: 30
calculation tasks: 10
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
Plint, M., Martyr, A.: Engine testing - Theory and practice, Butterworth-Heinemann, Oxford, 1997. ISBN 0-7506-1668-7. (на енглеском)
Grohe, H.: Messen an Verbrennungsmotoren, Vogel-Verlag, Würzburg, 1979. ISBN 3-8023-0087-4. (на немачком)
Holman, J. P.: Experimental methods for engineers. McGraw-Hill, 1984. ISBN 0-07-029613-8. (на енглеском)
Nachtigal, C. L.: Instrumentation and control. John Wiley & Sons, Inc., New York, 1990. ISBN 0-471-88045-0. (на енглеском)

IC Engines Mechatronics

ID: MSc-0855
responsible/holder professor: Miljić L. Nenad
teaching professor/s: Miljić L. Nenad, Mrđa D. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals

The aim of the course is to provide comprehensive insight into the specific subject matter of mechatronics systems used in IC Engines. To gain experience on functioning and using sensors and actuators specific for state of the art IC engines. To get closer acquaintance with the structure and architecture of the IC engine electronic control units (ECU), microcontrollers functions, in general, and methods of ECU software developing and testing.

learning outcomes

Ability to integrate specific electronic and mechanical engineering knowledge, with sound understanding of IC Engine mechatronic systems; More complete knowledge of IC Engine control; Ability to form IC Engine specific mechatronic system; Basic competence in ICE ECU programming and software testing; Knowledge in automotive bus communication, especially in ICE ECU data exchange.

theoretical teaching

Introduction to the mechatronics in IC Engines; Sensors and their characteristics; Measurement chains; Sensor calibration; "Intelligent" sensors; Sensing air/fuel ratio and exhaust gasses; Lubrication Oil monitoring sensor; Sensors of rotational and linear position and speed; Mass air flow sensors; IC Engine temperature and pressure sensors; Knock sensors; Actuators - classification; Power actuators (high voltage/current) and basics of power electronics; Ignition and Fuel injection system mechatronic components; Idle control; Waste gate and VVT actuators; AI/AO, DI/DO signals on uC; Digital signal acquisition; Peripheral uC devices; uC Communication interfaces; uC Hardware; Specific features of IC Engine uC; IC Engine specific functions realized on TPU blocks of Motorola (Freescale) uC; Software and programming methods - development environment, compiling, debugging; Software testing - SIL, PIL, HIL; Automatic control (basic principles repetition); Air/Fuel ratio control; Knock control; Adaptive control algorithms; Principles of Model Based IC Engine control and diagnostics; Engine speed based diagnostics and control algorithms; ICE ECU communication interfaces; Automotive communication buses and protocols - CAN, LIN, Flex Ray, K-Line, CCP;

practical teaching

In vivo demonstration of IC Engine mechatronic systems; Exercises with various automotive, IC Engine specific, sensors and actuators; uC programming (Freescale MPC 566, and MC68332) - basic ICE (gasoline fuel injection) control application based on TPU functions; SIL and PIL simulations; CAN communication - ECU calibration via CCP; IC Engine sensors and digital acquisition - Calculation tasks;

prerequisite

Exams passed on course “Electrical and electronics engineering” and at least one of : “ICE Fundamentals”, or “Engine fuelling and ignition systems”

learning resources

1. S.J. Popović, N. Miljić Handouts

2. IC Engine testing Laboratory (with an engine on the test bed)

3. DAQ System: National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461

4. Phytec pc-565 (Freescale MPC 565)
5. MCT GmbH Mega332 (Freescale MC68332)
6. National Instruments LabView 2012
7. Metrowerks CodeWarrior 8.x
8. WinEco MCT GmbH

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 12
calculation tasks: 3
seminar works: 0
project design: 0
consultations: 1
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 15
calculation tasks: 15
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
W. Bolton, Mechatronics, Pearson-Prentice Hall, 2003, ISBN 0 131 21633 3
U. Kincke, L. Nielsen: Automotive Control Systems, Springer Verlag, 2004, ISBN 3-540-23139-0;
R. Isermann, Modelgestuetzte Steuerung, Regelung und Diagnose von Verbrennungsmotoren, Springer Verlag, 2003, ISBN-10:3540442863, ISBN-13: 978-3540442863
BOSCH Gasoline Engine Management, ISBN 0-7680-0510-8
BOSCH Automotive Sensors, 2002, ISBN-3-934584-50-0

Internal combustion engines - M

ID: MSc-0866
responsible/holder professor: Popović J. Slobodan
teaching professor/s: Mrđa D. Predrag, Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals
The aims of the course are to provide a comprehensive insight into the subject matter of Internal Combustion Engines (theoretical operating cycle, real operating cycle, engine systems, engine operating characteristics). It is intended for students of the Internal Combustion Engines module as an in-depth introduction into studies of specific areas of Internal Combustion Engines, as well as for students of modules which require knowledge of Internal Combustion Engines as a power unit (Motor vehicles, Naval Architecture, Railway Mechanical Engineering, and Material Handling, Constructions and Logistics).

learning outcomes
Acquired theoretical and practical knowledge of Internal Combustion Engines. The ability to link fundamental engineering branches of thermodynamics, fluid mechanics, mechanics, strength of materials etc. into a complex unit such as engine. The ability of competent approach to engine selection, organization of exploitation and maintenance. Acquisition of solid base for tackling specific problems, design and construction of Internal Combustion Engines.

theoretical teaching
1. Introductory considerations.
2. Analysis of engine ideal thermodynamic cycles.
3. Engine real operating cycle: gas exchange process.
4. Combustion process in SI Engines.
5. Combustion process in CI Engines.
6. Engine working parameters
7. Engine supercharging.
8. Engine dynamic problems.
9. Engine operating characteristics.
10. Engine ecological problems.

practical teaching
Auditory exercises:
1. Engine design and Engine slider mechanism characteristics
2. IC Engine working medium, fuel characteristics and combustion
3. Numerical examples in engine thermodynamic cycles.
4. Fuel supply systems for SI and CI Engines.
5. Numerical examples in IC Engine working parameters, engine charging and heat balance.
6. Numerical examples in IC Engine supercharging

7. and Numerical examples of IC Engine slider mechanism kinematics and dynamics.

8. Engine systems and devices: ignition system, starting system, cooling system – air-cooled and liquid-cooled engines, lubricating system.

9. Numerical examples in IC Engine operating characteristics

10. Fundamentals of engine testing and preparation of laboratory exercises for engine testing.

Laboratory exercises:

1. Fuel supply systems for SI and CI Engines and engine electrical systems.

2. Testing of engine characteristics on the test bench.Аудиторне вежбе:

prerequisite
No prerequisites required.

learning resources
1. M. Tomić, S. Petrović: Internal Combustion Engines, FME, Belgrade, 2004, /In Serbian/ available at the FME Library

2. M. Tomić & S. Popović: Lecture notes (handouts) - Basics of Internal Combustion Engines, available in e-form in pdf on the site of the Chair of Internal Combustion Engines

3. IC Engine testing Laboratory (with an engine on the test bed)

4. Measuring-acquisition system: National Instruments PXI-1042-RT8186/5401/6123/6229/4070 /6602/8461

5. National Instruments LabView

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 9
laboratory exercises: 10
calculation tasks: 7
seminar works: 0
project design: 0
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 15
laboratory exercises: 10

calculation tasks: 25
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Miroljub Tomić, Stojan Petrović: Motori sa unutrašnjim sagorevanjem,Mašinski fakultet u Beogradu,ISBN 978-86-7083-646-4
Richard Stone: Introduction to IC Engines, SAE International, ISBN-13: 978-0768004953
John Heywood: Internal Combustion Engine Fundamentals, ISBN-13: 978-0070286375
C. R. Ferguson: Internal Combustion Engines, J.Wiley & Sons 1986, ISBN 0-471-88129-5

Marine Engines

ID: MSc-1025
responsible/holder professor: Knežević M. Dragan
teaching professor/s: Banjac B. Milan, Knežević M. Dragan, Stupar M. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written+oral
parent department: internal combustion engines

goals
The target of this subject is to give a comprehensive insight into the specific matter of IC marine engines, two-stroke, as well as four- stroke ones, and especially of high power engines with complex engine mechanism. The subject is intended for the students of Shipbuilding department who will be given an introduction for further later research into construction specifications of this class of engines and engine systems during professional practical work experience.

learning outcomes
General specifications: Adopted basic theoretical and practical knowledge in the field of IC marine engines where fundamental and applied scientific disciplines are entangled. Students acquire basic ability for competent approach to the choice, organization of exploitation and maintenance of diesel engines in the field of marine engine systems.

theoretical teaching
1.Introductory considerations 2.Specifications of the construction of marine engine parts- immovable and movable, marine engine distribution system 3.Fuel supply system and the supercharging system of the engine. 4. System of lubrication and cooling of the engine. Function, importance and types of lubricating oils for marine engines. Liquid cooling system. Air cooling system. 5. Engine starting and reversing system and operating characteristics of marine engines. Propelling characteristic of the engine. Optimization of the coupling: engine- propeller. 6. Marine engine vibrations. Torsion oscillations of the crankshaft and the transferring shafts. Possibilities of resonance occurrence and the method of its avoidance. 7. Choice of the marine engine as the most important marine driving machine.8. Presentation of marine engine supercharge systems. 9. Marine engine fundaments.

practical teaching
a) Auditory training: 1. Construction of marine engines. Presentation and analysis of different conceptions, and the construction of marine driving engines, from the lowest to the highest powers. 2. Marine diesel engine fuel supply system. Mechanical regulation systems (pump- pipe- injector, pump-injector), accumulator (common rail) systems, electronic regulated systems. 3.Supercharge engine system- presentation and analysis of the construction of the physical model of turbocharger. 4. Governors of the RPM of marine engines – function and types, division according to the place of assembly, analysis of the construction and the governor operational system. Analysis of the possibilities of electronic governor in optimization of marine diesel engine operating area marine diesel engines.

b) Laboratory training: Engine testing- measuring of the propelling characteristics of the engine.

prerequisite
No prerequisites required.

learning resources
Handouts, available in electronic version in PDF format on the site of IC Engine department. Instructions for the demonstration of laboratory experiment and electronic report writing laboratory installation-test bench with IC engine, measuring equipment and the software for measuring data acquisition.

number of hours: 45

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 24
auditory exercises: 18
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 25
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
Handouts, available in electronic version in PDF format on the site of IC Engine department.
Woodyard, D. F. (Ed.): Pounder's marine diesel engines and gas turbines - 8th edn., Elsevier Butterworth-Heinemann, Oxford,Burlington, 2004. ISBN 0-7506-5846-0.
Pounder, C. C.: Marine Diesel Engine, Butterworth & Co (Publishers) Ltd, Great Britain, 1972.

Mixture formation and combustion in IC engines

ID: MSc-1086
responsible/holder professor: Popović J. Slobodan
teaching professor/s: Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: internal combustion engines

goals
The aims of the course are to provide a comprehensive insight into the subject matter of Engine Fueling, Mixture formation and Ignition processes. Understanding the role, importance and principles of Engine Electronic Control. Broadening existing and acquiring new knowledge in hydrodynamics by studying high pressure phenomena occurring in fuel injection systems. Broadening knowledge in machine design by studying specific issues of high pressure pumps design principles. Broadening knowledge in electromechanics and electronics by studying processes occurring in Ignition Systems. Introduction into the field of Engine Sensors, Electronics and Mechatronics.

learning outcomes
Capabilities to develop, design, calculate and chose components of Engine Fueling and Ignition Systems. Capabilities to develop and organize maintenance procedures for both Fueling and Ignition Systems. Abilities related to specific issues of laboratory testing of Fueling and Ignition Systems and components. Developing practical skills for System set up and diagnostics.

theoretical teaching
Fuel spraying and mixture formation. Engine requirements regarding mixture strength. Carburetor basics – air & fuel flow, characteristics. Carburetor Auxiliary Systems. Fuel Injection Systems for SI Engines. Intake Port & Direct Fuel Injection, Hydraulic components, Sensors, Electronic Control Unit. Closed Loop Control. Fuel Injection Systems for CI Engines. High Pressure FI Pumps, Hydraulically operated Fuel Injectors and Nozzles. Common-Rail Fuel Injection Systems. Fuel Injection Dynamics. Electronic Control. Ignition Systems, Stages of operation, Ignition Spark - generation and characteristics. Spark Plug – Design and Characteristics.

practical teaching
Auditory exercises: Display and analysis of Carburetor based Engine fueling. Carburetor Design and Calculation. Display and analysis of SI Engines Fuel Injection Systems. Engine Sensors. Fuel Injector rated flow characteristics. Numeric examples for injection time determination. Injection time correction. Generation of basic Engine Injection Map. Diesel Fuel Injection Systems – numerical examples for HPP element & cam lobe design.

Laboratory exercises: Testing SI Engines Fuel Injection System components: Injector fuel rate determination (stationary, dynamic), Fuel Rail Dynamic Pressure measurement and analysis, Mass Air Flow-meter (MAFM) Characteristics measurement. Measurement and comparative analysis of MAFM and MAP sensor dynamics. Diesel Fuel Injection HP Pump Performance - Test Bench measurements. Measurement & Analysis of Diesel Fuel Injection System dynamics (injector pressure, injector needle travel). Measurement & Analysis of Ignition System Dynamics (ignition coil charge & discharge, ignition advance and spark plug ionization current).

prerequisite
Desirable: Good practical knowledge of Matlab/Simulink

learning resources
1. M. Tomić: IC Engines Fueling and Ignition Systems (in Serbian), Faculty of Mechanical Engineering, Belgrade, 2005.

2. M. Tomić, S. Popović: Extracts from Lectures (handouts), available in digital form

3. IC Engine testing Laboratory (with an engine on the test bed)

4. Flow Test Bench (in accordance to ISO 5167)

5. Diesel Injection System test Bench

6. DAQ System: National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461

7. National Instruments LabView

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 11
laboratory exercises: 14
calculation tasks: 4
seminar works: 0
project design: 0
consultations: 1
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 25
laboratory exercises: 35
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
J. Heywood: Internal Combustion Engine Fundamentals, Mc Graw-Hill, 1988, ISBN-13: 978-0070286375
G. Stiesch: Modeling Engine Spray and Combustion Processes, Springer-Verlag Berlin Heidelberg, 2003, ISBN 978-3-540-00682-4
C. Baumgarten: Mixture Formation in Internal Combustion Engines, Springer-Verlag Berlin Heidelberg, 2006, ISBN 978-3-540-30835-5

H. Zhao: Advanced direct injection combustion engine technologies and development Vol.1 i 2, Woodhead Publishing, 2010, ISBN 978-1-84569-732-7
C. Arcoumanis, T. Kamimoto: Flow and Combustion in Reciprocating Engines, Springer-Verlag Berlin Heidelberg, 2009, ISBN: 978-3-540-64142-1

Model Based Development of Automotive Software

ID: MSc-1088
responsible/holder professor: Miljić L. Nenad
teaching professor/s: Miljić L. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: internal combustion engines

goals

The aim of the course is to provide comprehensive insight into the methods and state-of-the-art tools for development and designing of embedded Automotive software; To provide students with knowledge needed for recognizing and accurate formulation of the automotive system tasks which could be realized through an embedded platform solution; To teach student how to use available methods, like model based modeling approach, and software tools for designing embedded automotive solutions with reliable software components.

learning outcomes

Upon the course completion, the student should be capable to:

- Recognize and Analyze the problem which could be solved through an embedded platform solution.
- Prepare specification of needed hardware and software components.
- Develop, implement and test software components.
- Test embedded component, both on a component and integrating system level.
- Calibrate models built in software components.

theoretical teaching

Introduction to the automotive control systems; Real-time systems and their application in automotive embedded solutions; Distributed computing solutions and automotive networks; Basics of AUTOSAR; Applicable standards in the process of Automotive software development; Software development process models; V Automotive model; Model based development; Automotive software modelling basics; Methods and tools in Automotive software development; Automotive software maintenance methods, tools and procedures;

practical teaching

Training: ETAS ASCET development environment; Development of automotive software components - from a concept to testing and calibration through series of guided examples.

prerequisite

No particular requirements for attending this course

learning resources

Handouts: Model base development of Automotive Software, available on the Moodle LMS platform of the IC Engines Dept.

Modeling and development environment: ETAS ASCET

Calibration: ETAS INCA

Hardware development platform: Phytec MPC565

HIL platform: NI RT-PXI, Labview, AVL BOOST, AVL CRUISE M

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 50
auditory exercises: 15
laboratory exercises: 19
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 1
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 55

references
Jörg Schäuffele, Thomas Zurawka: Automotive Software Engineering, Springer 2013, ISBN 978-3-8348-2469-1
Dieter Nazareth: Model Based Development of automotive Software, ETAS 2011

Numerical simulation of IC Engines processes - Basic approach

ID: MSc-0867
responsible/holder professor: Popović J. Slobodan
teaching professor/s: Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals

Acquiring new knowledge on role and importance of modelling dynamic processes in IC Engines. Broadening theoretical knowledge and analytical approach to thermodynamics, heat and mass transfer, fluid mechanics and fuel combustion by studying dynamic processes in IC Engine cylinder and collectors. Broadening knowledge and skills in applied computational methods and modular programming. Developing practical skills to design complex model structures and apply extensive and efficient numerical methods for studying and research of IC Engine dynamic processes.

learning outcomes

Understanding the reality and complexity of Heat Engines working cycles. Capabilities to design complex models and sub-models structures using multidisciplinary approach. Capabilities to analyse engine processes and performance using advanced simulation models. Establishing the Cause & Effect relationship between working cycle and engine performance.

theoretical teaching

1. Introduction to IC Engines processes modelling. Importance of mathematical modeling and computer simulation of engine working process for engine design optimization and improving of engine performances, energetic and ecological characteristics.
2. Basic model setup. Zero-dimensional model of real working cycle for engine cylinder as open thermodynamical system - equation setup based on first and second lows of thermodynamic and low of mass conservation. Basic sub-model structure.
3. Modeling of heat transfer to cylinder walls. Theoretical fundamentals and basic equations for the evaluation of heat transfer coefficient.
4. Thermodynamic properties of working medium. Working medium as ideal gas. properties of real gases. Component models. Equilibrium concentrations of combustion gases.
5. Modeling of gas flow through the restriction points (intake and exhaust valves, crevices) based on isentropic flow of compressible fluid. Analytical and experimental determination of flow coefficients. Gas leakage through crevices.
6. Modeling of engine combustion process (heat release). Types of engine heat release models. The model engine heat release based one stage and two stage Wiebe functions and the correlation of Viebe function parameters with engine type and engine speed and load. Quasi-dimensional models of engine heat release: model of turbulent flame front propagation for spark ignition engines; model of multi-zone combustion in fuel spray for diesel engines model Hiroyasu.
7. Flow in intake and exhaust plenums and pipes. Boundary conditions. Some methods to numerical solution of basic 1-D model.
8. Engine dynamics. Moment of inertia of reciprocating and rotating masses. Lumped mass model.
9. Mechanical losses in IC Engines. Basic empirical models.
10. Advanced topics in simulation of IC Engine processes. Multi-zone models. Quasi-dimensional and multi-dimensional models. In-cylinder pressure measurement and model based combustion analysis.

practical teaching

1. IC Engine working process simulation model - basic components and sub-models

2. Basic approach in IC Engine model development: example of single-cylinder engine model;

3. Simulacija visokopritisnog dela ciklusa bez sagorevanja;

4. Heat transfer model - examples of basic sub-models development and their application;

5. Thermodynamic properties of working fluid- examples of basic sub-models development and their application;;

6. Modelling flow through valves and ports

7. Heat release basic models - examples and application and comparative analysis;

8. 1-D flow models in pipes and plenums - basic approach and application;

10. Integration of sub-models;

11. Development of engine low-level simulation models using model libraries

12. Mechanical losses in IC Engines - basic empirical models and application;

13. High-level models application - example of two-zone model;

14. High-level models application - example of quasidimensional model.

prerequisite

Good practical knowledge of Matlab/Simulink

learning resources

Mathworks Matlab/Simulink IDE (Licenced)

Ricardo WAVE – 1D Engine and gas dynamics simulation software package (Licenced)

LMS Imagine.Lab AMESim – Simulation software for modelling and analysis of 1D systems (Licenced)

Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)

DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 4
laboratory exercises: 12
calculation tasks: 10
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 2
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 8
check and assessment of lab reports: 0
check and assessment of seminar works: 0

check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 50
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 30

references

J. Heywood: Internal combustion engines fundamentals, McGraw-Hill 1988, ISBN 9780-070-28637-5
F. Pischinger: Verbrennungskraftmaschinen Thermodynamic, Springer Verlag, ISBN
G. P. Merker et. al.: Simulating combustion and pollutant formation for engine development, Springer Verlag, ISBN 10 3-540-25161-8, 13 978-3-540-25161-3
R. Benson: The Thermodynamics and Gas Dynamics of Internal Combustion Engines, Vol 1, Vol. 2, Clarendon Press, Oxford, 1982, ISBN 0-19-856210-1
R Jankov: Diesel engine gas-thermodynamic processes and performance modelling (in Serbian), Naučna knjiga, Beograd, 1984

Selected topics in IC Engines 1

ID: MSc-1026
responsible/holder professor: Popović J. Slobodan
teaching professor/s: Knežević M. Dragan, Miljić L. Nenad, Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: internal combustion engines

goals
Acquiring new knowledge on role and importance of modelling dynamic processes in IC Engines. Broadening theoretical knowledge and analytical approach to thermodynamics, heat and mass transfer, fluid mechanics and fuel combustion by studying dynamic processes in IC Engine cylinder and collectors. Broadening knowledge and analytical approach to the mixture formation, fuel jet break-up, fuel droplet formation and evaporation. Broadening knowledge and skills in applied computational methods and modular programming. Developing practical skills to design model structures and apply numerical methods within project-oriented tasks related to IC Engines and HPS design and application.

learning outcomes
Understanding the reality and complexity of Heat Engines working cycles. Capabilities to design models and sub-models structures using multidisciplinary approach. Capabilities to analyse engine and HPS processes and performance using simulation models. Establishing the Cause & Effect relationship between working cycle and engine performance.

theoretical teaching
1. Gas flow in intake and exhaust ports and collectors. 1-D modelling of dynamic gas flow in pipes. Optimization of Intake and exhaust plenum geometry by maximizing engine volumetric efficiency.

2. Supercharging/Turbocharging of IC Engines. System design and simulation. Optimization of IC Engine-Turbocharger system performance. Charge Air intercooler design and simulation.

3. High efficiency thermodynamic engine cycles. Combining high expansion – to – compression ratio with supercharging in real engines.

4. Fuel mixture formation in High-Pressure injection systems. Simulation and modelling of dynamic procesess in fuel pipes and injectors. Primary and secondary Break-Up, drop formation and evaporation.

5. Mechanical losses in IC engines. Modelling engine friction and auxillaries power consumption. Experimental determination of mechanical losses distribution.

6. In-cylinder and port flow multidimensional modelling using CFD.

7. Selected topics in Engine exhaust and noise emission. Exhaust gas concentration modelling based on chemical reactions kinetics and chemical equilibrium. Exhaust gas emission measurement.

8. Hybrid Powertrain Systems simulation and optimisation. 1-D modelling of dynamic performance of HPS. Optimization οφ energy storage capacity and mass, drive performance and arrangement for best fuel efficiency

9. Alternative fuels. Fuel physical properties and specific design issues related to fuel properties. Specific issues related to mixture formation and combustion of alternative fuels.

10. Engine components Design and manufacturing issues. Specific manufacturing and production technologies. Turbocharger design and production. Impeller design and manufacturing. Impeller and housing materials selection for improved performance.

practical teaching

Literature and technical solutions survey and theoretical analysis. Development and application of numerical simulation models of engine processes, engine components or systems dynamic performance. System analysis by application of simulation models taylored to specific project-oriented task. Experimental verification. Reporting and results presentation.

prerequisite

Passed exam on course: IC Engines Processes

learning resources

Mathworks Matlab/Simulink IDE (Licenced)
AVL Advanced Simulation Tools (AST): Boost, Fire, Excite, Cruise
LMS AMESim
Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)
DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 18
consultations: 2
discussion and workshop: 0
research: 10

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 30

references

Selected books from premium publishers: Springer Verlag, Teubner, McGraw-Hill, Butterworth-Heinemann, Elsevier
Extensive selection of articles and papers: IMechE, SAE, JSAE, ASME, MTZ/ATZ, Elsevier etc.

Selected topics in IC Engines 2

ID: MSc-1027
responsible/holder professor: Miljić L. Nenad
teaching professor/s: Knežević M. Dragan, Miljić L. Nenad, Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: internal combustion engines

goals
Acquiring new knowledge in the area of thermal piston machinery through analysis of the working cycle and particularities of piston compressors with reciprocating and rotational pistons. Broadening theoretical knowledge and analytical approach in the field of mathematical modelling and engine simulations through: model based fault diagnosis on various engine subsystems; Mean value models used in real-time engine control; Broadening knowledge in the area of automated engine mapping and calibration trough acquaintance with the state-of-the-art tools and techniques.

learning outcomes
Built skills for proper selection, calculation and design of piston compressor units. Practical experience gathered through realization of model-based diagnosis system on IC Engine. Understanding of crucial Mean-value models used in Engine control; Practical experience in building and testing a small scale engine subsystem control application; Understanding and acquaintance with the state-of-the-art mapping and modeling tools, principles and procedures.

theoretical teaching
1. Particularities of the piston mechanism, kinematics and dynamics of piston compressor's piston mechanism; Crankcase force balancing in the multi cylinder / multi stage piston compressors; Compression of real gases, its mixtures and moist mixtures on high pressures; Real thermodynamic cycle of a piston compressor; Multi stage compression; Design and calculation of piston compressor parts; Auxiliaries and flow and pressure control systems; Maintenance issues.
2. Model based principles of technical system fault diagnosis; Model base fault diagnosis of engine subsystems (faults on engine's air path, mixture formation, cylinder processes inequalities, cylinder misfire,...)
3. Engine control algorithms; Mean-value models and their application in engine real time control
4. State-of-the-art methods in the engine mapping and calibration process. Problems and challenges of multi parameter optimization with multiple boundary conditions on modern SI and CI engines. Principles of model based calibration.

practical teaching
1. Building a code for piston compressor real working process simulation. A project task with a goal for proper determination of the piston compressor unit design concept, its design calculation.
2. Practical experience of building model based fault diagnosis system (detection of air path leaks or obstructions; detection of cylinder processes inequalities on a multi cylinder engine; misfire detection; model based real-time combustion parameter estimation)
3. Building an engine subsystem control system based on the application of common mean-value models (idle control, ignition system control, mixture formation system control,...)
4. Experience and practical work with the Inca calibration system (ETAS) on a engine test bed.
5. Experience and practical work with the tool for an automated engine mapping and calibration - Cameo (AVL)

prerequisite
Passed exam on course: "IC Engines Processes" and "Engine Mechatronics"

learning resources

Mathworks Matlab/Simulink IDE (Licenced)

AVL Advanced Simulation Tools (AST): Boost, Fire, Excite, Cruise

LMS AMESim

AVL Cameo; AVL Concerto;

Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)

Laboratory instalation with a reciprocating piston and Roots type compressor.

DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 18
consultations: 2
discussion and workshop: 0
research: 10

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 30

references

R. Jankov: Piston Compressors, Faculty of Mechanical Engineering, Belgrade, 5th edition, 1990, (on Serbian)
Isserman, R.: Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance
Kiencke, U., Nielsen, L. : Automotive Control Systems: For Engine, Driveline, and Vehicle
Guzzella, L., Onder, C.: Introduction to Modeling and Control of Internal Combustion Engine Systems
Paulweber, M.,Lebert, K.: Mess- und Prüfstandstechnik: Antriebsstrangentwicklung · Hybridisierung ...

Sensors and Computer Based Measurements

ID: MSc-0959
responsible/holder professor: Miljić L. Nenad
teaching professor/s: Miljić L. Nenad, Mrđa D. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: internal combustion engines

goals
The aim of the course is to provide comprehensive insight into the sensors and digital acquisition systems (DAQ), measurement systems and, mainly, their usage in the field of systems testing in the area of Mechanical Engineering; To introduce students the world of virtual instrumentation and graphical programming environment (LabVIEW) which is dedicated to development of DAQ applications. To gain experience on functioning and using DAQ systems through numerous, real world, examples. To get closer acquaintance with the sensors, and digital acquisition software & hardware, in general, and methods of DACQ software developing and testing.

learning outcomes
Ability to integrate sensors and DAQ hardware in measurement chains in order to fulfill specific requirements in the field of mechanical engineering system testing & measurements. Ability to build and test software application (LabVIEW virtual instruments) for measurement and automation of various mechanical engineering systems. Practical knowledge in computer based measurements of fundamental engineering data. Supplied basic knowledge and practice in LabView environment sufficient to apply for a test and getting a degree of certified CLAD programmer.

theoretical teaching
Measurement Techniques; Measurement of Non-Electrical Quantities (Sensors and Sensor Systems, Displacement and Angles, Speed, Acceleration, Force, Torque, Pressure, and Mass, Temperature, Flows, Signal Conditioning); Digital Measurement Techniques (Discretisation of Amplitude and Time, Sampling Theorem, Quantization, A/D and D/A Converters, Measurement of Frequency, Counters); Architecture and basic principles of data acquisitions systems (DAQS); Measurement Errors and Statistics; Static and Dynamic Behavior of Sensors.

practical teaching
Introduction to the Virtual Instrumentation (VI) and LabVIEW development environment; Data flow in VI; Troubleshooting and Debugging Vis; Implementing a VI; File I/O Techniques; Common Design Techniques and Patterns; Managing Hardware resources; Synchronization Techniques; Event Programming; Error Handling; Controlling the User Interface; Improving an Existing VI; Practice labs with various sensors and measurement chains building tasks. Student Project: Building a DAQ with given requirements (complied with the Student's module syllabus);

*)National Instruments (NI) Labview courses "Core 1" & "Core 2" are incorporated in the theoretical and practical teaching of this course. This course is in compliance with the "LabVIEW Academia" program and therefore offers students all benefits stated in LabVIEW Academia agreement.

prerequisite
No particular requirements for attending this course

learning resources
Handouts: N. Miljić, Computer Based Measurements & Virtual Instrumentation

DACQs: National Instruments USB 6008, MyDAQ, PXI ,...

Graphical Development Environment: National Instruments LabView 2010 with modules and toolkits (LVA package)

Auxiliary platforms: Demo board for simulation of analog and digital signals; Universal Amplifying / Conditioning board for various sensors; Driver board for DC and step motors.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 43
auditory exercises: 20
laboratory exercises: 19
calculation tasks: 0
seminar works: 0
project design: 3
consultations: 0
discussion and workshop: 1
research: 0

knowledge checks: 12
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 3
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 10
final exam: 40
requirements to take the exam (number of points): 42

references
Holman, J. P.: Experimental methods for engineers. McGraw-Hill, 2007. ISBN 0071181652 .
Labview Core 1 & 2 Course Manual & Exercises, National Instruments
J. Hoffmann: „Taschenbuch der Messtechnik“, 4. Aufl., Hanser, 2004
Robert Bishop: LabVIEW 2009 Student Edition, Prentice Hall, 2010, ISBN13- 9780132141291
J. Niebuhr, G. Lindner: „Physikalische Messtechnik mit Sensoren“, 5. Aufl., Oldenbourg, 2005.

Skill Praxis M - MOT

ID: MSc-1222
responsible/holder professor: Knežević M. Dragan
teaching professor/s: Knežević M. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: internal combustion engines

goals
Acquiring practical knowledge of mechanical engineer's duties. Gaining knowledge about company's structure, management and quality system.

Practical knowledge of manufacturing processes and corresponding machine tools. Broadening and acquiring new knowledges in the fields of IC engines research and testing.

learning outcomes
Understanding company's structure and connections between various company parts. To comprehend the importance of teamwork in everyday engineering practice. Gaining practical skills in the field of CAD/CAE/CAM/CAT.

theoretical teaching
Introduction. The role and importance of engineering practice in engineers education. Instructions on how to keep diary of practical training and how to write seminar paper. Recommendations on proper company selection for practical training. A two-stage practical training is expected: first stage in companies that design and build engines, engines parts and systems. Second stage will be in the Center of IC Engines, where students participates in design and completion of engine test beds, measuring systems and software production and testing, as well as participation in engine testing processes.

practical teaching
a) consultations during practical training; b) practical training b1. practical training in selected company (2/3 of practical training); b2. practical training in the Center of IC Engines (1/3 of practical training).

prerequisite
Passed exams: Engine Working Processes, Engine fuelling and ignition systems. Company's agreement to accept a student for practical training.

learning resources
Instructions for Engineering practice to carry out, (PDF file). Computers and licensed software in the Center of IC Engines. Test beds for engines and engine systems testing at the same center.

number of hours: 90

active teaching (theoretical): 10
lectures: 5
elaboration and examples (revision): 5

active teaching (practical): 70
auditory exercises: 0
laboratory exercises: 40
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 10

discussion and workshop: 10
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 6

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 40
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Supercharging of IC Engines

ID: MSc-0856
responsible/holder professor: Popović J. Slobodan
teaching professor/s: Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals

Acquiring new knowledge on role and importance of turbocharging in IC Engines. Developing skills to calculate parameters of supercharging and match compressor/turbine to desired engine performance. Broadening knowledge of thermodynamics by studying compressor/turbine performance characteristics and processes occuring in intercooler. Broadening knowledge in machine design by studying specific issues of turbocharger design principles.

learning outcomes

Understanding the reality of Heat Engines working cycles and complexity of their design. Establishing the Cause & Effect relationship between working cycle and machine design. Capabilities to calculate parameters of IC Engine Supercharging, to make proper selection of Supercharging System components (compressor, turbine, intercooler, Waste-Gate). Abilities related to specific issues of laboratory testing of Supercharging System Components.

theoretical teaching

1. Definitions and Survey of IC Engine Supercharging Methods; 2. Matching Flow Capacities and Characteristics of IC Engine and Charging Compressor; 3. Mechanical Supercharging; 4. Exhaust Gas Turbocharging; 5. Intercooling; 6. Calculation of Supercharging; Supercharging by means of Gasdynamic effects; 7. Design of Turbochargers; 8. Special issues and specific solutons of Supercharging;

practical teaching

a) 1. Numerical examples in IC Engines Supercharging 2. Display & Analysis of Supercharging Methods, Design and Performance Characteristics of Compressors, Turbines & Intercoolers; 3. Preparation for Laboratory Task; 4. Principles of Modeling & Simulation of Supercharging System Components in Matlab/Simulink; Simulation of Supercharged IC Engine using Matlab/Simulink;

b)Student Project Task: Calculation of Supercharging System and matching Compressor/Turbine Characteristics to desired IC Engine Performance.

c) Laboratory Task: - Testing Compressor on Test Bench;

prerequisite

Passed exam on course "IC Engines processes".

Good practical knowledge of Matlab/Simulink

learning resources

1. M. Cvetić: Extracts from lectures (handouts) in e-form

2. S. Popović: Numerical examples, in e-form

3. IC Engine testing Laboratory (with an engine on the test bed)

4. Turbo-compressor Flow test bench

5. DAQ System: National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461

6. National Instruments LabView Graphical Development Environment

7. Matlab/Simulink Software Package

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 5
calculation tasks: 14
seminar works: 0
project design: 2
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 10
laboratory exercises: 10
calculation tasks: 15
seminar works: 0
project design: 15
final exam: 50
requirements to take the exam (number of points): 0

references
H. Hiereth, P. Prenninger: Charging the Internal Combustion Engine, Springer Verlag 2003, ISBN 978-3-211-33033-3
Watson, N., Janota, M. S.: Turbocharging the Internal Combustion Engine. Macmillan Press, London, 1982. ISBN 0-333-24290-4.
Zinner, K.: Aufladung von Verbrennungsmotoren. Springer-Verlag, Berlin, 1985. ISBN 3-540-15902-9. (in german)
John Heywood: Internal Combustion Engine Fundamentals, ISBN-13: 978-0070286375.

Engine Design Project

ID: MSc-1023
responsible/holder professor: Knežević M. Dragan
teaching professor/s: Knežević M. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: oral
parent department: internal combustion engines

goals
Gaining experience through practical work on the design of IC engines. The practical application of knowledge from previous IC engines courses, expansion and acquisition of new knowledge in the field of design and calculation of machines, materials and production methods of machine parts. Introduction to modern methods of design in mechanical engineering, especially in the field of IC engines. Understanding and gaining practical experience in working with computer aided design and calculation methods (CAD - 2D, 3D, CAE).

learning outcomes
Understanding the whole complex mechanical structures, the connection of individual parts and components, ability to design a functional and well-designed machines. The ability of practical application of modern software tools for designing in mechanical engineering. The capability to design, making good material and production methods selection of the most important parts of internal combustion engines. Selection and dimensioning of auxiliary systems and components needed for proper engine functioning.

theoretical teaching
The role of standardization and unification in the IC engine design. Phases of the classical approach to the design of the engine (sequential design). Definition of technical terms; Selection of the most important process and operating parameters in the construction of a new engine. Making of preliminary design and the main engine project. Preparation of workshop drawings. Testing and refinement of the prototype design; Simultaneous (parallel) design; Computer aided design; Technology of rapid prototyping; Mathematical modeling of working processes of Otto and Diesel-engine; Modeling of the fundamental elements of the Engine structure, the calculation by means of FEM.

practical teaching
Development of the project of the IC Engine - assembly drawings of the cross and longitudinal sections; 3D modeling (CAD) of one of the most important parts of the Engine and making workshop documentation for that part; Consultations in the preparation of the project.

prerequisite
Passed exams in Engine Working Processes and IC Engine Design 1.

Skills in using 2D & 3D CAD software

learning resources
- M. Cvetić: Extracts from lectures (handouts)

- 2D & 3D CAD CAE Software & Workstations

number of hours: 30

> **active teaching (theoretical):** 10
> lectures: 5
> elaboration and examples (revision): 5

active teaching (practical): 10
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 30

references
Basshuysen, R. von, Schaefer, F.: Internal Combustion Engine Handbook, SAE, Warrendale, 2004. ISBN 0-7680-1139-6.
Challen, B., Baranescu, R. (ed.): Diesel Engine Reference Book, 2nd Ed., Butterworth-Heinemann, Woburn, 1999. ISBN 0 7506 2176 1.
Mollenhauer, K., Tschoeke, H. (ed.): Handbook of Diesel Engines. Springer-Verlag, Berlin, Heidelberg, 2010. ISBN 978-3-540-89082-9.
Yamagata, H.: The science and technology of materials in automotive engines. Woodhead Publishing Limited, Cambridge, 2005. ISBN 1-85573-742-6.

Engine Working Processes

ID: MSc-0852
responsible/holder professor: Popović J. Slobodan
teaching professor/s: Popović J. Slobodan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: internal combustion engines

goals

The aims of the course are: Gaining basic theoretical and practical knowledge about physicality of real engine working processes. Making a complete spark ignition and diesel engine working cycle calculation. Analysis of engine working process integral working parameters and operating characteristics.

learning outcomes

Merging a theoretical knowledge of thermodynamics and fluid mechanics, connecting and application on real object – internal combustion engine.

Training for basic modeling and calculating of real engine working process, as well as acquiring fundamentals of engine designing.

Mastering of engine working parameters and operating characteristics and of the influences of working process on operating, energetic and ecologic engine characteristics.

theoretical teaching

1. Analysis of thermodynamic ideal cycles. Engine real working cycle; fundamentals of cycle modeling. 2. Gas exchange process; gas flow through the channels and valves. Gas exchange in 4-stroke engines; valve timing; indicators of gas exchange process quality. Gas exchange in 2-stroke engines. Compression process. 3. Combustion in spark ignition engine; phases, influencing factors and process calculation. 4. Combustion in diesel engine; phases, influencing factors and process calculation. Diesel engine types according to the method of mixture formation. Expansion process. 5. Engine integral working parameters: indicating parameters, mechanical losses and effective parameters. Analysis of engine fuel consumption and specific effective work (mean effective pressure). Engine energetic balance. 6. Engine operating characteristics: speed and load characteristics, propeller and universal characteristics.

practical teaching

1. Analysis of thermodynamic ideal cycles; numerical examples of engine ideal thermodynamic cycles. 2. Gas exchange process in 4-stoke engines. Numerical examples: evaluation of gas exchange specific work, coefficient of residual gases and volumetric efficiency. Display of various gas exchange systems and types of 2-stroke engines. 3. Display of various spark ignition engines combustion chambers and their comparison. Display of various diesel engines combustion chambers and their comparison. 4. Instruction for engine working process calculation. Example of spark ignition engine working process calculation. Example of diesel engine working process calculation. Examination of student's engine working process calculation report.

prerequisite

No prerequisites required.

learning resources

1. M. C. Živković: Engine theory, Faculty of Mechanical Engineering, Belgrade, 1982.

2. M. Tomić, S. Petrović: Internal combustion engines, Faculty of Mechanical Engineering, Belgrade, 2008.

3. S.Petrović, M.Tomić: Engine working processes- handouts, available in PDF format at the Department of IC engines.

4. Test bench for internal combustion engines testing, Department of IC engines

5. Measuring-data acquisition system National Instruments PXI-1042 RT8186/5401/6123/6229/4070/6602/8461 (APC)

6. National Instruments LabView 7.1 (PPO)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 9
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 0

references
Heywood J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, Inc., 1988.
Djačenko N. H., Teorija dvigatelei vnutrennego sgorania – rabočie procesi, Mašinostroenie, Lenjingrad, 1974.
Orlin A. S., Kruglov M. G., i dr.,Teorija rabočih procesov poršnevih i kombinirovanih

MATERIAL HANDLING, CONSTRUCTIOS AND LOGISTICS

Computer Aided Design in Material Handling Practice

ID: MSc-0909
responsible/holder professor: Gašić M. Vlada
teaching professor/s: Gašić M. Vlada
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: material handling, constructios and logistics

goals
Basic goals of this course are: 1) introduction to finite element method and applications in design of structures for material handling machines, 2) gaining the practical skills for 2D and 3D design and modeling of structures of material handling machines.

learning outcomes
After the completion of the course, student is trained to:

- Apply the finite element method (FEM), with linear finite elements, in formulation and calculation of plane trusses and frames
- Perform static analysis of plane truss and frame in FEM software and work and present basic technical report for given engineering problem
- Form the 3D structural model with linear finite elements and give static analysis due to loads
- Use different FEM software for structural analysis
- Do the basic design of gantry crane according to engineering recommendations

theoretical teaching
Introduction to finite element method. The FEM analysis process for beams and truss elements. Member stiffness matrix. Coordinate transformation. Master stiffness matrix. Force vector. Solving for displacements. Recovery of internal forces and stresses. Examples of finite element models of structures of material handling machines. Modeling of 3D truss systems.

practical teaching
Matrix method for calculation of displacements, internal forces and stresses in 2D truss system with 5 nodes. Matrix method for calculation of displacement and internal forces at plane two beam-elements model. Modeling the characteristic structures for material handling machines, in finite element software (trusses, beams, frames, cranes). Preparation for input data and analysis of output data. 3D modeling in given software of some parts of material handling machines.

prerequisite
Necessary: Mathematics 2, Strength of materials

Advisable: Fundamentals of steel structures.

learning resources
1. Computer room 516

2. FEA softwares

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 8
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 15
laboratory exercises: 45
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Handouts with examples

Construction, mining and conveying machinery elements

ID: MSc-0790
responsible/holder professor: Bošnjak M. Srđan
teaching professor/s: Bošnjak M. Srđan, Gnjatović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: material handling, constructios and logistics

goals
Basic course goals are: 1) introducing students to construction, design and calculations of basic construction, mining and conveying machinery elements; 2) mastering of practical skills required for design and calculation of construction, mining and conveying machinery.

learning outcomes
Goal of this course is to introduce the students to the following skills:

- Modeling and calculation of unique below-the-hook lifting devices;
- Design, modeling and calculations related to fundamental substructures of crawler systems;
- Modeling and calculation of bearing structures of mobile construction, transport and mining machines;
- Design and calculation of stabilizers;
- Computer-aided modeling and creating technical documentation of elements and assemblies of machines used in construction, mining and material handling processes.

theoretical teaching
Construction, mining and conveying machinery drive. Mechanical and hydraulic power transmission systems. Basic mechanisms of construction, mining and conveying machines. Design and calculation of specific construction, mining and conveying machinery elements.Travel mechanisms. Rail-mounted travel gear. Crawler travel gear. Hydraulic walking gear. Track wheels. Crawler chain link. Two wheel bogie. Crawler bearing structure. Traction systems. Drive and transmission systems calculations. Design and calculation of carriage and traction traverse. Supporting-slewing mechanisms. Types, design solutions, calculation. Mechanisms for excavating device reach alternation. Types, design solutions, calculation. Mechanisms for working devices lifting and propulsion. Stability calculation. Stabilizers.

practical teaching
Design and calculation of various types of joints. Design and calculation of eye plates and hooks for special purposes. Design and calculation of travel gear track wheels. Travel gear two wheel bogies. Design and finite element analysis of crawler two wheel bogie body. Design and calculation of crawler chain links and pads. Design and calculation of additional bearing structure of mobile machines. Design and calculation of stabilizers. Construction documentation. Consultations.

prerequisite
Engineering Graphics, Strength of Materials, Material Science, Machine Elements 1, Machine Elements 2, Fundamentals of steel structures

learning resources
Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001., Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references
Momir M. Plavšić, Construction Machines, Scientific Book, Belgrade, 1990.
Vinko Jevtić - Construction and Mining Machines, Faculty of Mechanical Engineering Nis, 1993.

Conveying and Material Handling Machines

ID: MSc-0308
responsible/holder professor: Zrnić Đ. Nenad
teaching professor/s: Zrnić Đ. Nenad, Zrnić Đ. Nenad, Zrnić Đ. Nenad, Zrnić Đ. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: material handling, constructios and logistics

goals
The main goal of this course is to acquaint students with material handling machines and conveying machines, types and design solutions and principles of work. The goal is to introduce students to master the practical skills needed to perform the engineering profession, such as the main machine parameters, load analysis, selection of drive units and calculation of the capacity.

learning outcomes
By completing this course student acquires ability to:

- determine bulk and solid materials characteristics
- determine conveying machine's throughput/capacity in accordance with project requirements and type of conveyed material
- calculate and choose conveyor drive
- calculate basic parameters and components of belt conveyor
- calculate basic basic parameters and components of apron conveyor
- calculate basic basic parameters and components of screw conveyor
- calculate basic basic parameters and components of bucket elevator

theoretical teaching
Determination of the transport capacity of material handling and conveying machines. Conveyors, belt conveyors, apron conveyors, flight conveyors, overhead conveyors, elevators, screw conveyors, oscillating conveyors, roller conveyors, gravity conveyors, hoppers, feeders and gates , ropeways, basic performances of machines, structural solutions, basic calculations. material handling machines with translator motion, bridge and gantry cranes, unloading bridges, container cranes, performances, operational principles, analysis of load, calculations. material handling machines with rotational motion, jib cranes, tower cranes, portal cranes in ports, performances, structures, mechanisms. Elevators and industrial trucks, forklifts, storage cranes.

practical teaching
Calculation of conveyors with belt pulling element, the contour calculation and selection of propulsion belt conveyors, calculation around conveyor sections, calculation of conveyors with chain pulling element, apron and flight conveyors, calculation of bucket elevators, roller conveyors, screw conveyors. Video presentations of modern design of material handling machines, analysis of the machine operation in system, automation of work.

prerequisite
The conditions are defined by the curriculum of the study program.

learning resources

1. Nenad Zrnic: Conveying and Material handling machines - Hanouts and written lectures, 2011, DVL.

2. Slobodan Tosic, Material handling equipment - Mechanization of transport, Mechanical Engineering, Belgrade, 1999, KDA.

3. Slobodan Tosic, D. Ostric: Cranes, Faculty of Mechanical Engineering, 2005, KDA.

4. Computers, Laboratory 516, ICT / CAH

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 10
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 60
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Cranes Design

ID: MSc-0139
responsible/holder professor: Zrnić Đ. Nenad
teaching professor/s: Zrnić Đ. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: material handling, constructios and logistics

goals
The main objective of this course is to achieve competence of students to master the principles of cranes design and that is able to be incorporated into the cranes design process in the future engineering work. The goal is to master specific practical skills for the selection of drive units, calculation of support steel structures of cranes and to get the knowledge on the standards for calculation, as well as realization of technical documentations.

learning outcomes
Upon successful completion of this course, students should be able to:

- identify, classify and analyze regular, occasional and exceptional load at overhead travelling cranes
- perform calculation and selection of the bridge crane geometry
- determine the load of the bridge crane in characteristic cross section
- perform proof of stress, proof of deformation, proof of dynamic stiffness, proof of elastic stability, proof of bolted connection between the main girders and end

carriages

- perform calculation and choose stiffnesses
- perform calculation of end carriages
- carry out the verification of the analytical calculation with the results obtained in the FEM software package

theoretical teaching
The basic principles of cranes design, trends in development, maintenance, transportation and crane installation, testing and registration of cranes, safety measures. Standards for calculation of support structures of cranes, trolley selection, sizing and calculation of trolley supporting structure and its drive. Calculation of support structure of bridge cranes, the selection of geometry of main girders and end carriages, proof of stress, proof of deformation, proof of dynamic stiffness, loads of main girder, proof of welded connections. Elastic stability of girder, local stability of plate, calculation of the connections of main girders and end carriages, calculation of end carriage, specificities in calculation of the single girder bridge cranes.

practical teaching
Realization of the project of double girder crane, selection of drive units, selection of geometry and calculation of support structures of trolley and crane, proof of elastic stability - buckling of plates, calculation of single girder bridge cranes. Computer exercises, calculation of supporting structure of bridge cranes by using FEM, with training in the use and application of specialized software package KRASTA (Cranes Statik, non-commercial academic version without restrictions concerning calculations), for static and dynamic analysis of supporting structures of material handling and conveying machines by using finite elements method.

prerequisite
The conditions are defined by the curriculum of the study program.

learning resources
1. Nenad Zrnic: handouts - Written lectures, 2011, DVL

2. Slobodan Tosic, D. Ostric: Cranes, Faculty of Mechanical Engineering, 2005, KDA.

3. KRASTA - Program for statical and modal analysis of spatial frames, MANUAL, DVL.

4. Computers, Laboratory 516, ICT / CAH

5. KRASTA software package - program for statical and modal analysis of spatial frames, BSB Kühne GmbH, ICT / CSP

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 35

references

Design of construction and mining machines subsystems

ID: MSc-0791
responsible/holder professor: Bošnjak M. Srđan
teaching professor/s: Bošnjak M. Srđan, Gnjatović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: material handling, constructios and logistics

goals
Basic course goals (objectives): 1) introducing students to specificity of working process, construction, design and calculation of fundamental subsystems of construction and mining machines; 2) mastering practical skills which are necessary for design and calculation of construction and mining machines.

learning outcomes
This course offers the following skill set to the students who complete it:

- Design of backhoe excavators' working devices;
- Design of basic elements of single-bucket excavators' working devices;
- Modeling and calculation of a bucket wheel excavator's working device – bucket wheel body and buckets;
- Design and calculation of the bucket wheel drive system;
- Design and calculation of four and eight-wheel bogie of a crawler mechanism;
- Calculation of basic technical and technological parameters, power and strength of jaw and conic rock crushers;
- Load analysis, modeling, proper supporting, loading and finite element analysis of civil and mining machines' fundamental subassemblies.

theoretical teaching
Short survey of construction and mining machines development. Shovel excavators. Calculation of working loads caused by soil excavation. Calculation of basic geometrical parameters of bucket of back hoe excavator, power shovel and dragline excavator. Defining parameters of drive and transmission system of working device of shovel excavator. Design solutions of elements of working device of shovel excavator. Shovel excavator's working device strength calculation. Design and calculation of dozer, scraper and grader mechanisms. Multi bucket excavators. Basic design of bucket wheel excavator. Bucket wheel excavator working device. Bucket wheel, buckets. Bucket wheel drive. Determination of bucket wheel boom basic parameters. Bucket chain excavator. Basic design of bucket chain excavator. Working device of bucket chain excavator. Theoretical fundaments of crushing process. Jaw, cone, roll and impact crushers – design, calculation. Theoretical fundaments of screening process. Static and dynamic screens - design, calculation.

practical teaching
Design of back hoe excavator working device. Shaping of working device basic elements. Selection of hydro cylinder. Design of basic elements of shovel excavator working device. Design and calculation of dozer working device. Design and calculation of bucket wheel excavator working device. Design and calculation of bucket wheel with buckets. Design, construction and calculation of bucket wheel drive. Design and calculation of four wheel and eight wheel bogie of bucket wheel excavator crawler travel gear. Calculation of basic technical-technological parameters, power and strength of jaw and cone crushers. Construction documentation. Consultations.

prerequisite
Engineering Graphics, Strength of Materials, Material Science, Machine Elements 1, Machine Elements 2, Fundamentals of steel structures

learning resources
Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001., Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 10
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references
Momir M. Plavšić, Construction Machines, Scientific Book, Belgrade, 1990.
Vinko Jevtić - Construction and Mining Machines, Faculty of Mechanical Engineering Nis, 1993.

Eco Design

ID: MSc-0127
responsible/holder professor: Zrnić Đ. Nenad
teaching professor/s: Zrnić Đ. Nenad, Zrnić Đ. Nenad, Zrnić Đ. Nenad, Zrnić Đ. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: material handling, constructios and logistics

goals

The main objective of this course is to achieve competence and academic skills in the field of eco design and sustainable product development. The goal is mastery of the methodologies to define strategies to improve products and reduce the harmful effects of products on the environment, and understanding of the impact of products on the environment throughout its life cycle and innovative approach to obtaining environmentally improved products.

learning outcomes

By completing this course student acquires ability to:

- analyse life cycle of a product using tools for life cycle assessment
- implement ecodesign strategies into design process and product development
- suggest measures for improvement of environmental performances of the product
- implement legislative in the field of ecology into design process
- design and develop sustainable product

theoretical teaching

Introduction into Eco-design, basic concepts and terminology, the impact of products on the environment. Eco-Design strategy, product modeling, recommendations for the selection of materials with low impact on the environment, the impact of production technologies, transport and packaging, as well the phase of product use and product end-of-life on the ecological impacts. The assessment of product life cycle, methodology of environmental impact, practical examples. Environmental communication and the EU measures for environmental protection, directive, eco-labels and declarations. Application of Eco-Design for the improvement of existing products. Design for disposal and recycling of waste products, design for waste minimization, design for dismantling of old equipment.

practical teaching

Terminology of Eco Design. Examples of impacts of products on the environment. Examples of eco-design strategies. Examples of analysis of product life cycle in terms of Eco-Design. Examples of improvements of existing products. Examples of disposal and recycling of used goods. Eco Design computer tools, training and work in a computer tool EcoDesign Pilot + Assistant + EEG, obtaining an improved product through several stages which include the identification of products, Eco Design strategies and concrete measures for improvement.

prerequisite

The conditions are defined in curriculum of the study program.

learning resources

1. Nenad Zrnic: Ecodesign, Handouts - Written lectures, 2011, DVL.

2. Computers with Internet connection, Lab 455, ICT / CAH

3. EcoDesign Pilot software + + Assistant EEG, TU Wien, ICT / CSP

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Ostad - ECODESIGN Sustainable Product Development, Vienna University of Technology, 2006, KCJ.

Facility layout and industrial logistics

ID: MSc-0187
responsible/holder professor: Kosanić Ž. Nenad
teaching professor/s: Kosanić Ž. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: material handling, constructios and logistics

goals
Introducing the students into the factories, factory facilities, transport and warehouse systems design process logic is the main goal. Development of the student system design creative and innovative abilities in order to increase the production, warehouse and logistic activities efficiency, contributing to the overall country industrial development is also the main issue.

learning outcomes
Upon successful completion of this course, students should be able to:

- Make a project requirement for factory, factory facilities, transport, storage and logistic systems planning.

- Make a calculation of needed technological and additional equipment, working power, working places, needed areas and material flow.

- Make a layout of the factory, factory facilities, transport, storage and logistic systems.

- Calculate the basic elementary subsystems performances (by queueing systems modeling) of the factory, factory facilities, transport, storage and logistic systems.

- Make a cast iron foundry concept study.

theoretical teaching
Systematic design approach. Systems building. Feasibility studies. Design task. Main production programs. Production and technical production capacities. Factories subsystems and workshops. Technological project documentation. Design procedure. Production systems working regime. Working time fund. Production equipment needs estimation. Working space needs estimation. Working power needs estimation. Layout design. Flexible manufacturing systems definition, application fields and main characteristics. Layout design models. Material flow. Main logistic chain managing principles. Elementary subsystems (knot points) main characteristic. Queuing systems main foundations. Material flow analyzing models. Basic layout design inputs. Energy supply. Heating, ventilation and de-dusting. Master plan. Case studies and topics consulting.

practical teaching
Queuing model choosing for characteristic production and transport processes modeling. Computer calculation of queuing models statistics (outcome working parameters). Foundry concept study: Smeltery department production equipment needs estimation; Molding sand preparation department technology choosing and production equipment needs estimation; Core sand preparation department technology choosing and production equipment needs estimation;Mold cleaning department technology choosing and production equipment needs estimation; Foundry warehouse design; Some department crane or conveyer basic design parameters and capacity estimation; Foundry layout design; Foundry one department detailed layout design. Consulting and recommendations for factories, factory facilities, transport and logistic (warehouse-distributive) subsystems and systems modeling and designing.

prerequisite
Needed:

Passed Subject: Mathematical probability and statistics, Material handling equipment, Fundamental of steel structures in heavy machinery.

learning resources
1, Dj. Zrnic, Facility layout design, Faculty of mechanical engineering, University of Belgrade, 1993.; 2, Dj. Zrnic, M. Prokic, P. Milovic, Foundry layout design, Faculty of mechanical engineering, University of Belgrade, 1998.; 3, Dj. Zrnic, D. Savic, Material flow simulation, Faculty of mechanical engineering, University of Belgrade, 1997.; 4, Dj. Zrnic, D. Petrovic, Facility layout design solved example problems, Faculty of mechanical engineering, University of Belgrade,, 1992.; 5, Queuing models software package, Faculty of mechanical engineering, University of Belgrade, 1999., lab, 459.

number of hours: 75

active teaching (theoretical): 20
lectures: 18
elaboration and examples (revision): 2

active teaching (practical): 40
auditory exercises: 0
laboratory exercises: 3
calculation tasks: 0
seminar works: 0
project design: 35
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 3
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references
Dj. Zrnic, Facility layout design, Faculty of mechanical engineering, University of Belgrade, 1993.
2, Dj. Zrnic, M. Prokic, P. Milovic, Foundry layout design, Faculty of mechanical engineering, University of Belgrade, 1998.
Dj. Zrnic, D. Savic, Material flow simulation, Faculty of mechanical engineering, University of Belgrade, 1997.

Dj. Zrnic, D. Petrovic, Facility layout design solved example problems, Faculty of mechanical engineering, University of Belgrade,, 1992.
Queuing models software package, Faculty of mechanical engineering, University of Belgrade, 1999., lab, 459.

Fundamentals of Mining and Construction Machines Dynamics

ID: MSc-0491
responsible/holder professor: Bošnjak M. Srđan
teaching professor/s: Bošnjak M. Srđan, Gnjatović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: material handling, constructios and logistics

goals
Basic course goals (objectives): 1) introducing students with specificities of dynamic processes of construction and mining machines . 2) mastering practical skills which are necessary for analysis of dynamic behavior of construction and mining machines.

learning outcomes
By successfully completing this course the student should acquire the following competences:

- Properly forming the reduced dynamic models of earthmoving machines such as single-bucket excavators and bulldozers;
- Determining elementary technical and exploitation characteristics of the machines used for material preparation and handling (rock crushers and sifters), accounting for dynamic effects occurring in such processes;
- Modeling the excitation of continuous excavators and analysis of the influence of constructional and working parameters of the machine on the excitation caused by resistance to excavation;
- Creating dynamic models of continuous excavators' substructures;
- Identification and analysis of continuous excavators' substructures response to excitation caused by resistance to excavation;
- Calculation and proper selection of basic parameters of conveyor belts with relatively high conveyor speed, dominantly used in mobile continuous earthmoving machines.

theoretical teaching
Fundamentals of basic excavating machines dynamics – backhoe excavators and bulldozers. Fundamentals of dynamics of raw material fragmenting and sorting machines – crushers and screening machines. Modeling of excitation of excavators for continuous excavation. Influence of design and work parameters on excitation caused by resistance to excavation. Modeling of bearing construction and mechanisms of excavators for continuous excavation. Identification and analysis of excavators for continuous excavation dynamic response on excitation caused by resistance to excavation. Vibrations caused by self-excitation. Dynamic response of bearing structure (construction) on excitation caused by wind. Dynamic of spreaders, mobile machines for continuous excavation (material handling).

practical teaching
Dynamic models of single bucket excavator excavating devices. Impact of Bulldozer to the obstacle. Calculation of basic parameters of crushing and screening machines. Bucket wheel excavators and trenchers excitation modeling (determination). Analysis of bucket wheel excavators bearing structure dynamic response on excitation caused by resistance to excavation Dynamic response of bearing structure (construction) on excitation caused by wind. Fundamentals of spreader dynamics. Consultations.

prerequisite
Required previously passed courses: Strength of Constructions, Structural and Stress Analysis, Mining and Construction Machines.

learning resources
1. Computers, Laboratory 516

2. Software Mathlab, Catia

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 19
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 5
discussion and workshop: 1
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 6
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 30
requirements to take the exam (number of points): 35

references
Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001.
Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008.
Srđan Bošnjak, Fundamentals of Mining and Construction Machines Dynamics, - Instructions for seminar paper realization, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008.
J.P. Den Hartog, Mechanical Vibrations, McGraw-Hill Book Company, Inc., USA, 2007.

Mining and Construction Machines

ID: MSc-0102
responsible/holder professor: Bošnjak M. Srđan
teaching professor/s: Bošnjak M. Srđan, Gnjatović B. Nebojša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: material handling, constructios and logistics

goals
Basic course goals (objectives): 1) introducing students with specificities of working process, design, modeling and calculation of basic (fundamental) subsystems of construction and mining machines and appliances, primarily machines for continuous excavation and machines for crushing and screening. 2) mastering practical skills which are necessary for design and calculation of construction and mining machines.

learning outcomes
By successfully completing this course the student should be able to competently assess the following problems:

- Choosing a proper design and calculating rotating supports and mechanisms of earthmoving machines' revolving superstructures:
- Choosing a proper design and calculating basic parameters of the earthmoving machines' movement mechanisms;
- Determining and adopting basic parameters of the bucket wheel excavators' (BWE) and bucket chain excavators' drive systems;
- Proper strength calculation of open-pit mining machines' substructures using linear Finite Element Method (FEM);
- Coupling of experimental and analytical data with the goal of properly determining parameters of BWE static stability;
- Comparison of design approaches and calculation of basic parameters of jaw, conic, gyratory, roll crushers and impactors according to required degree of material fragmentation.

theoretical teaching
Design solutions and calculations of slewing platforms and mechanisms of excavators. Design solutions and calculations of crawlers and walking mechanisms for excavator movement. Use, working process, structural scheme, drive and transmission systems and calculation of bucket wheel excavators and bucket chain excavators. Analytical and experimental methods of determination of static stability parameters. Theoretical fundaments of crushing process. Jaw, cone, roll and impact crushers – design, calculation. Theoretical fundaments of screening process. Static and dynamic screens - design, calculation.

practical teaching
Calculation of working (excavating) equipment, operating modes, and power of mechanisms of excavators for continuous excavation. 3D modeling of characteristic subassemblies of excavators for continuous excavation. Calculation models of truss substructures of bucket wheel excavators. Computer simulations of external loads. Load cases. Stress – strain identification. Creation (Development) of technical drawings. Position determination, selection and calculation of basic (main) parameters of stackers (spreaders). Calculation of basic technical (design) and technological parameters, power and strength of jaw and cone crushers and screens. Consultations.

prerequisite
Defined by the curriculum of the study program

learning resources
1. Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001., 2. Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008., 3. Srđan Bošnjak, Mining and construction machines - Instructions for writing laboratory reports, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008., Computers, Laboratory 459(516), 5. Software Mathlab, (Catia)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Vinko Jeftić, Construction and Mining Machines, University of Niš, Faculty of Mechanical Engineering, Niš, 1993.
Momir M. Plavšić, Construction Machines, Scientific Book, Belgrade, 1990.

Skill Praxis M - TKL

ID: MSc-1197
responsible/holder professor: Bošnjak M. Srđan
teaching professor/s: Bošnjak M. Srđan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: material handling, constructios and logistics

goals
The goal of the course is to inform students about the resources, machines and devices in the field of material handling used in various industries, especially in industry, construction, mining, transport,tourism, energy, process engineering, service industries, etc.

learning outcomes
The successful completion of course students are introduced to: 1 Production processes in companies that produce or use the funds for material handling, 2 Intralogistics, 3 Processes, maintenance of equipment and machinery for machinery, and others.

theoretical teaching
Introduction in material handling. Basics of the measures for safety and health at work when using the equipment and resources to work in general, especially in material handling. The basic principles of machines and devices for machinery. Fundamentals of technological processes in industry to manufacture machinery and construction machinery in the area. Fundamentals of design of transport and logistics systems.

practical teaching
Practical teaching is realized througout the visits of the big industrial facilities and companies where are used and produces machines and devices for material handling in order to comprehend the material flow within intralogistics, production and technological characteristics of the processes needed for the realization of the devices, asembly process, maintenance, structural characteristics of the cranes and hoists, role of the engineering machines in building sites, role of the conveying systems and bucket wheel excavators within the open pits, warehouse and distribution systems... Also, it is performed presentation of the realized projects (designs) from the department in 10 year period. It is shown used methods, basic phases in the design processes (starting from the sketch up to final solutions), along with technical solutions for reconstruction of some machines for material handling.

prerequisite
No conditions.

learning resources
Tošić, S.: Transportni uređaji - Mehanizacija transporta, Beograd, 1999., Ostrić, D., Tošić, S.: Dizalice, Beograd, 2005, Petković, Z.: Metalne konstrukcije u Mašinogradnji, Beograd, 1996., Bošnjak, S.: Rotorni rovokopači, Beograd, 2001., Zrnić, Đ., Prokić,M., Milović, P.: Projektovanje livnica, Beograd, 1988.

number of hours: 90

active teaching (theoretical): 10
lectures: 5
elaboration and examples (revision): 5

active teaching (practical): 70
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 50
project design: 0
consultations: 10
discussion and workshop: 10
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 60
project design: 0
final exam: 30
requirements to take the exam (number of points): 10

references
Tošić, S.: Transportni uređaji - Mehanizacija transporta, Beograd, 1999.,
Ostrić, D., Tošić, S.: Dizalice, Beograd, 2005.
Petković, Z.: Metalne konstrukcije u Mašinogradnji, Beograd, 1996.
Bošnjak, S.: Rotorni rovokopači, Beograd, 2001.
rnić, Đ., Prokić,M., Milović, P.: Projektovanje livnica, Beograd, 1988.

Structural and Stress Analysis

ID: MSc-0910
responsible/holder professor: Gašić M. Vlada
teaching professor/s: Gašić M. Vlada
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: material handling, constructios and logistics

goals
Basic goal of this course is introduction to principles in design and calculation of steel structures for wide range of material handling machines (mining machines, earthmoving machines, cableways and lifts). Also, goal is development of student creative skills for designing the light but safe structures, i.e. rational structures.

learning outcomes
After the completion of the course, student is trained to:

- Calculate the shear stresses of the thin-walled closed section, such as on box girder of bridge crane
- Calculate first moments of area of the thin-walled open section
- Obtain the position of the shear centre of the thin-walled open section and form the warping coordinate
- Analyze the warping torsion effects for beams and cantilevers with thin-walled open section, determine the warping loads and calculate the stresses due to bimoment and warping torsion
- Perform the complete stress proof of girders made of thin-walled open section

theoretical teaching
Theory of elasticity (basics). Stress-strain relations. Torsion of solid and hollow circular section bars. Torsion in thin-walled closed section beams. Torsion in thin-walled open section beams. Shear flow distribution. Shear stress distribution. Shear centre. Warping. Warping constant. Lateral buckling. Equation for rotational angle. Representation of stresses.

practical teaching
Calculation of section properties for thin-walled open section beams: centre of gravity, first moment of area, second moment of area, torsional constant, warping constant. Determination of shear centre for various thin-walled open sections. Calculation of shear stress distribution and bending stress distribution at characteristic sections performed on several types of thin-walled open section simple beams and cantilevers under loads. Determination of shear centre for thin-walled sections with developed software package.

prerequisite
Necessary: Mathematics 1,Mathematics 2, Strenght of materials.

Advisable: Fundamentals of steel structures

learning resources
Computer rooom 516, literature.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Zoran Petkovic: Metalne konstrukcije u masinogradnji 2, Faculty of Mechanical Engineering, Belgrade, 2005.
Vlada Gašić: Osnove metalnih konstrukcija u mašinogradnji, Handbook, Faculty of Mechanical Engineering, Belgrade, 2017

Transport and logistic systems design

ID: MSc-0119
responsible/holder professor: Kosanić Ž. Nenad
teaching professor/s: Kosanić Ž. Nenad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: material handling, constructios and logistics

goals
Introducing the students into the advanced transport, warehouse and logistic (warehouse-distributive) systems design process logic is the main goal. Development of the student system design creative and innovative abilities in order to increase the material flow, warehouse and logistic activities efficiency, contributing to the overall country industrial development is also the main issue.

learning outcomes
Upon successful completion of this course, students should be able to:

- Specify elementary subsystems, elementary subsystem variables, elementary subsystem performance variables and environment variables of the flexible transport systems.

- Calculate the basic elementary subsystems performance variables (by queueing systems modeling) of the flexible transport and logistic systems.

- Make a comparison of different flexible transport system applications.

- Make a calculation of needed capacity, technological and additional storage equipment, working power, working places, needed areas and material flow of the storage and logistic systems.

theoretical teaching
System, elementary subsystem and environment variables and performance variables of the flexible transport system (FTS). FTS elementary subsystems. "Power and free" system main design characteristic. Flexible monorail system main design characteristic. Rail automated vehicle system main design characteristic. Automated guided vehicle system (AGVS) main design characteristic. Required flexible transport systems vehicle fleet estimation. Warehouse and logistic (warehouse-distributive) systems fundamental design characteristics: goods receiving subsystem, main warehouse subsystem, order picking subsystem, goods dispatching subsystem. One dimensional non strategy and strategy order picking models. Two dimensional order picking models. Case studies (with pointing out most important design parameters). Exercises of lectures.

practical teaching
Exercises of order picking models. Concept design of conventional warehouses with different warehouse technologies, hay-bay warehouses with different automation level and logistic (warehouse-distributive) systems: Goods receiving and dispatching subsystems area estimation, goods receiving and dispatching subsystems technology choosing, main warehouse subsystem technology choosing and capacity estimation,order picking subsystem technology choosing and capacity estimation; Storage equipment technical specification; Required applied transport systems vehicle fleet estimation; System performance variable estimation; Storage system layout design; Warehouse and logistic systems design recommendation and consultation.

prerequisite
Needed: Passed Subject: Mathematical probability and statistics, Material handling equipment, Facility layout and industrial logistics.

learning resources

1, Dj. Zrnic, Facility layout design, Faculty of mechanical engineering, University of Belgrade, 1993.; 2, Dj. Zrnic, M. Prokic, P. Milovic, Foundry layout design, Faculty of mechanical engineering, University of Belgrade, 1998.; 3, Dj. Zrnic, D. Savic, Material flow simulation, Faculty of mechanical engineering, University of Belgrade, 1997.; 4, Dj. Zrnic, D. Petrovic, Facility layout design solved example problems, Faculty of mechanical engineering, University of Belgrade,, 1992.; 5, Queuing models software package, Faculty of mechanical engineering, University of Belgrade, 1999., lab, 459. 6. Lecture handouts.

number of hours: 75

active teaching (theoretical): 20
lectures: 18
elaboration and examples (revision): 2

active teaching (practical): 40
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 10
seminar works: 5
project design: 20
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 3
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 20
final exam: 30
requirements to take the exam (number of points): 35

references

1, Dj. Zrnic, Facility layout design, Faculty of mechanical engineering, University of Belgrade, 1993.
2, Dj. Zrnic, M. Prokic, P. Milovic, Foundry layout design, Faculty of mechanical engineering, University of Belgrade, 1998.
3, Dj. Zrnic, D. Savic, Material flow simulation, Faculty of mechanical engineering, University of Belgrade, 1997.
4, Dj. Zrnic, D. Petrovic, Facility layout design solved example problems, Faculty of mechanical engineering, University of Belgrade,, 1992.
Lecture Handouts

MECHANICS

Analitical mechanics

ID: MSc-0825
responsible/holder professor: Jeremić M. Olivera
teaching professor/s: Jeremić M. Olivera, Obradović M. Aleksandar, Radulović D. Radoslav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: mechanics

goals
-To provide students knowledge of the fundamental principles and methods in Analytical Mechanics

-To enable students to solve practical problems in Analytical Mechanics using acquired knowledge in Analytical Mechanics

- to monitoring novelties in science and engineering

learning outcomes
-To enable students to master terms, methods and principles in Analytical Mechanics

-To enable students to relate the knowledge from knowledge in other scientific fields with knowledge Analytical Mechanics

-To apply knowledge from Analytical Mechanics in analysis, synthesis and prediction of solutions and consequences of problems in science

- To monitoring novelties in science and engineering

theoretical teaching
Analytic system dynamics. Free and constrained material systems. Constraints and their classification. Real, possible and virtual displacements. Number of degrees of freedom. Virtual work of forces. Ideal constraints. Lagrange's equations of the first kind. Lagrange's mechanics and differential approaches. Elements of tensor calculus. State of motion of mechanical system in configuration space. Kinetic energy. Generalized forces. Virtual work principle. Lagrange-D'Alembert's principle. Lagrange function. Lagrange's equations of the second kind for holonomic mechanical systems and their structure. First integrals. Lagrange's equations of the second kind for nonholonomic mechanical systems.

Hamiltonian mechanics. Hamilton's variables. Phase space. Hamilton's function and its structure. Hamilton's canonic equations for conservative and nonconservative holonomic mechanical systems. Direct method for finding first integrals of Hamilton's canonic equations. Poisson bracket. Liouville's theorem. Whittaker's equations. Routh's equations.

Variational principles. Elements of variational calculus. Relation between general dynamic equation and variational calculus. Central equation of dynamic. Second form of Hamilton's principle. Hamilton-Jacobi method of integration of canonic equations. Lagrange principle.

practical teaching
Analytic system dynamics. Free and constrained material systems. Constraints and their classification. Number of degrees of freedom. Virtual work of forces. Ideal constraints. Lagrange's equations of the first kind.

Lagrange's mechanics and differential approaches. Elements of tensor calculus in analytical mechanics.Kinetic energy. Generalized forces. Virtual work principle. Lagrange-D'Alembert's principle. Lagrange function. Lagrange's equations of the second kind for holonomic mechanical systems and their structure. First integrals. Lagrange's equations of the second kind for nonholonomic mechanical systems.

Hamiltonian mechanics. Hamilton's variables. Hamilton's function and its structure. Hamilton's canonic equations for conservative and nonconservative holonomic mechanical systems. Direct method for finding first integrals of Hamilton's canonic equations. Whittaker's equations. Routh's equations.

Variational principles. Elements of variational calculus in mechanics. Hamilton-Jacobi method of integration of canonic equations.

prerequisite
Defined by curriculum.

learning resources

[1] Leko M., PlavšićM., Solved problems from tensor calculus with application in mechanic, Naučna knjiga, Beograd,1973.

[2] Fempl S., Elements of variational calculus, Građevinska knjiga, Beograd, 1965.

[3] Lurje A.I., Analytical mechanics, Gosud.izdav. F.M., Moskva, 1961.

[4] Bakša A., Rational mechanics, Lectures 1999/2000, Beograd, 2000.

[5] Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 0

references

Simić S. S.,Analytical Mechanics, Fakultet tehničkih nauka, Univerzitet u Novom Sadu, Novi Sad, 2006
Vuković J., Selected topics in Mechanics, Written lectures for PhD studies, Mašinski fakultet u Beogradu, Beograd
Gantmaher F. R., Analytical Mechanics, Zavod za udžbenike, Beograd, 1965.
Anđelić T., Tensor Calculus, Naučna knjiga, Beograd, 1980.
Vujanović B., Optimization Methods, Radnički univerzitet " Radivoj Ćirpanov", Novi Sad, 1980.

Biomechanics of tissue and organs

ID: MSc-0559
responsible/holder professor: Lazarević P. Mihailo
teaching professor/s: Lazarević P. Mihailo
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: oral
parent department: mechanics

goals
To introduce students to the application of fundamental principles and laws of biomechanics of tissues and organs in order to understand and study them. Establishment of appropriate biomechanical model of tissue and organs using modern theory of viscoelasticity, the possibility of simulations based on them in order to confirm the experimental data, the possibility of applying for the purposes of design and design basis of the same. It allows the potential cooperation with experts in medicine or work in specialized clinical institutions.

learning outcomes
•Applying basic principles and laws linear theory of elasticity (LTE), the basics of continuum mechanics to understand and study the biomechanical properties and characteristics of human tissues and organs (HTO)

• Identify the most important rheological properties of considered HTO

• Distinguish between (Kelvin-Voigt, Maxwell model, Standard linear solid (SLS) model) on the basis of the linear theory of viscoelasticity (LTV)

• Forming the appropriate rheological models HTO applying LTE in time and frequency domain

• Numerical simulate the previously formed rheological models using programming environment (MATLAB, etc.).

• Identify the properties and characteristics of non-linear and plastic behavior considered HTO

theoretical teaching
Introduction to the biomechanics of tissues /organs. Introduction to continuum mechanics, transport phenomena, the basics of biofluids. Basic assumptions of linear theory of elasticity (LTE). Modeling based on the theory LTE. Biomechanical properties of blood vessels: the arterial system, venous sistem. Vascular anatomy, ventricular geometry and hemodynamics. Dynamics of biomechanical heart model. Biomechanics of the lungs. Biomechanics of the nervous and lymphatic tissue.

The dynamic behavior of biological tissues / organs: the relaxation of stress, creep, hysteresis. Introduction to the theory of viscoelasticity (TV):

Kelvin-Voigt and Maxwell model. Basic assumptions of the theory of nonlinear elasticity - the finite elastic deformation. Nonlinear dynamic behavior of tissues / organs. Elements of cell rheology. Tolerance of tissue / organ to impact loads.

Injury of the organ / tissue - the biomechanical modeling them. Biomechanical engineering to prevent tissue trauma. Biomechanical aspects of the growth of tissues / organs. Engineering tissues and organs. History and perspectives of future development of artificial tissue/organ

practical teaching
Introductory examples of tensor analysis. Biomechanical properties of hard tissues such as tooth-and bone man. Biomechanical properties of soft connective tissues-such as muscle, the muscle fibers. Biological-tissue modeling using LTE. Examples: elastin, collagen, cartilage-props. Modeling the

behavior of biological tissue using LTVE: for example lung tissue, blood vessels. Biomechanical models of the respiratory, nervous and lymphatic systems. Structure and function of pulmonary parenhina. Examples of dynamic behavior of biological tissues / organs: the stress relaxation, creep, hysteresis. The case of the dynamic behavior of the diaphragm. An illustrative example of the final elastic deformation. Examples povrde organs / tissues: head and spinal cord-biomechanical models of the same. Tolerance of organs / tissues to impact operećenja. The growth of tissues and organs - such as bones. Examples of artificial models of tissues /organs (body parts).

prerequisite

desirable courses: Fundamentals of biomedical engineering, Human anatomy and physiology, Biomechanics of the human locomotor system

learning resources

[1]Y. C.Fung,Biomechanics:Mechanical Properties of Living Tissues, Springer, Berlin,2000.

[2]Писани изводи са предавања (handouts),

[3]М.Лазаревић, Биомеханика ткива и органа,(скрипта у припреми),2013

[4]Joseph D.Bronzino,«Tissue Engineering and Artificial Organs (The Biomedical Engineering Handbook),CRC Press,2006.

[5]D.Schneck,J.Bronzino,Biomechanics principles and applications,CRC Press, New York,2003.

[6]National Instruments-LABVIEW,(ЦСП)

[7]WWWinternetlaboratorije,MATLAB,

number of hours: 45

active teaching (theoretical): 18
lectures: 8
elaboration and examples (revision): 10

active teaching (practical): 17
auditory exercises: 6
laboratory exercises: 3
calculation tasks: 4
seminar works: 0
project design: 2
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 1
check and assessment of projects: 1
colloquium, with assessment: 2
test, with assessment: 1
final exam: 3

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0

seminar works: 0
project design: 15
final exam: 30
requirements to take the exam (number of points): 35

references

S. Cowin, S. B.Doty,Tissue Mechanics, Springer Science+Business Media, LLC,2007
Ed. Joseph D. Bronzino,The Biomedical Engineering HandBook, Second Edition. Boca Raton: CRC Press LLC, 2000
M,Lai,D.Rubin,E.Crempl, Introduction to Continuum Mechanics,Pergamon Press,1993.
H.A. Barnes,J.E Hutton,K. Walters F. R. S, An Introduction to rheologyI,Elsevier Amsterdam ,1993
C. Oomens, M. Brekelmans, F. Baaijens,Biomechanics: Concepts and Computation,Cambridge University Press,,2009

Continuum Mechanics

ID: MSc-1315
responsible/holder professor: Zorić D. Nemanja
teaching professor/s: Zorić D. Nemanja, Tomović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: seminar works
parent department: mechanics

goals
To introduce students continuum mechanics as applied form of classical mechanics. Aim of this subject is to students overcome and understand terms of continuum mechanics, i.e., to familiarize basic principles Euler's and Lagrange's approach to continuum, as well as basic of tensor calculus.

learning outcomes
Upon successful completion of this course, students should be able to:

• form Green (Lagrangian) strain tensor;

• form Eulerian strain tensor;

• form velocity strain tensor;

• determine the stress tensor components;

• compose general equation of motion (Navia) of any deformable medium;

• form continuity equation (conservation of mass);

• apply the theorem of the change in total energy of a continuous medium in integral form.

theoretical teaching
Continuum hypothesis. Lagrange's and Euler's approach to continuum. Material derivative. Surface and volume forces. Stress tensor. Symmetry of stress tensor. Cauchy's principle. Major stress and directions of major stress. Extreme values of main stresses. Mohr's circle. Deformation gradient. Deformation tensor. Displacement vector. Infinitesimal deformation and rotation. Deformation energy. Hooke's law. Characteristic of fluids. Divergence and rotor of velocity vector. First Helmholtz's theorem. Velocity of deformation. Acceleration – Kelvin's theorem. Vortex and nonvortex circulations. Law of conservation of mass – continuity equation. Sources and abysses. Euler's equation. Laws of change of momentum and angular momentum. Inner forces. Stress assumptions. Navier-Stokes equations. Constitutive equations.

practical teaching
Application of tensor algebra and analysis. Determination of stress components. Deformations in Lagrange and Euler sense. Calculation of major deformations. Stress and displacement tensor. Continuity equation. Navier-Stokes equations. Constitutive equations.

prerequisite
Defined by curriculum.

learning resources
Reddy, J.N., An Introduction to Continuum Mechanics, Second Edition, Cambridge University Press, 2013.

Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Reddy, J.N., An Introduction to Continuum Mechanics, Second Edition, Cambridge University Press, 2013.

Mechanics M

ID: MSc-0004
responsible/holder professor: Mitrović S. Zoran
teaching professor/s: Zorić D. Nemanja, Jeremić M. Olivera, Lazarević P. Mihailo, Mandić D. Petar, Mitrović S. Zoran, Mladenović S. Nikola, Obradović M. Aleksandar, Radulović D. Radoslav, Tomović M. Aleksandar, Trišović R. Nataša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: mechanics

goals
The aim of this course is that students learn the elements of the dynamics of the oscillatory motion of a particle, the dynamics of variable mass particle, advanced problems in kinematics of a particle, kinematics of a complex motion of a rigid body and mechanical system of rigid bodies as well as the dynamics of spherical and general rigid body motion, the approximate theory of gyroscope and the impact theory.

learning outcomes
Upon successful completion of this course, students should be able to:

• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.

• Analyze the motion of variable mass particle.

• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.

• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.

• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.

• Solve problems related to the impact (collision) of a particle and rigid body.

theoretical teaching
Rectilinear oscillation (vibration) of a particle. Free and forced, damped and undamped oscillations of a particle. Decrement of oscillations. Tremors. Resonance. Dynamic amplification. Resonant diagrams. Dynamics of a variable mass particle. Kinematics of a particle in curvilinear coordinates. Kinematics of the general motion of a rigid body. Kinematics of the complex motion of a rigid body. Synthesis of motions of a rigid body. Introduction to the kinematics of rigid body systems. Dynamics of spherical and general body motion. Approximate theory of gyroscope. Gyroscopic torque. The basic impact theory. The impact coefficient. Theorems about the changes of linear and angular momentum during the impact.

practical teaching
Rectilinear oscillation (vibration) of a particle. Free and forced, damped and undamped oscillations of a particle. Decrement of oscillations. Tremors. Resonance. Dynamic amplification. Resonant diagrams. Dynamics of a variable mass particle. Kinematics of a particle in curvilinear coordinates. Kinematics of the general motion of a rigid body. Kinematics of the complex motion of a rigid body. Synthesis of motions of a rigid body. Introduction to the kinematics of rigid body systems. Dynamics of spherical and general body motion. Approximate theory of gyroscope. Gyroscopic torque. The basic impact theory. The impact coefficient. Theorems about the changes of linear and angular momentum during the impact.

prerequisite
Defined by the curriculum study of graduate studies program.

learning resources
[1] Pavišić, M., Golubović, Z., Mitrović, Z., Mechanics - Dynamics of mechanical systems, Faculty of Mechanical Engineering, Belgrade, 2011.

[2] Vuković, J., Simonović, M., Obradović, A., Marković, S., Collections of examples for Dynamics, Faculty of Mechanical Engineering, Belgrade, 2007.

[3] Mladenović, N., Trišović, N., Dynamics, Faculty of Mechanical Engineering, Belgrade, 2015.

[4] Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 10
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
Pavišić, M., Golubović, Z., Mitrović., Z., Mechanics, Dynamics of System, MF Belgrade, 2011.
Djuric, S., Dynamics and theory of oscillations, MF Belgrade, 1987.
Rusov, L., Dynamics, Naučna knjiga, 1988.

Mechanics of robots

ID: MSc-0007
responsible/holder professor: Lazarević P. Mihailo
teaching professor/s: Lazarević P. Mihailo
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: mechanics

goals
Introduce students to basic concepts of kinematics and dynamics of robotic systems. It is possible to solve direct and inverse kinematics and dynamics of the robot system (RS) using modern theory based on Rodriguez transformation matrix as well as the theory of finite rotations. Determination (simulation) models of RS - i.e. differential equations of motion of the RS, which are important in practical problems of the RS.Practical simulations RS using Cyberbotics Webots software package and students work with laboratory robot NEUROARM.

learning outcomes
•Determine the number of degrees of freedom of robotic system (RS)

•Define the matrix of transformation, in the case of (Euler angles, Rezal angles, Hamilton-Rodrigues parameters, ...)

• Forming expressions to determine the basic kinematic characteristics RS using Rodrigues approach: characteristic position vectors of RS, speed and acceleration of the center of inertia of the robot segments (RSE), angular velocity and angular acceleration RSE, speed and acceleration of the robotic gripper

• Forming a kinematic model RS and solve direct and inverse kinematics task of RS

• Analyze singular cases in solving the task of kinematics RS

• Formed terms of linear momentum, angular momentum and kinetic energy of arbitrary segment RS

• Determine the kinetic energy of the whole RS, the basic metric tensor RS, the corresponding generalized forces, Christoffel symbols of the first kind for given RS

• Forming the differential equations of motion using the RS covariant form of Lagrange equations of the second kind and solve other types of direct and inverse task of dynamics

• Numerical simulate the previously formed kinematic / dynamic models using programming environment (MATLAB, Mathematica, etc.)

• Forming the differential equations of motion RS for the case of RS: which is given in the form of a kinematic chain with branching , RS given in the form of a closed kinematic chain.

• Set additional constraint equations in the case of constrained robotic gripper movements

• Distinguish non-redundant and redundant RS and determine the degree of redundancy RS

• Distinguish the basic concepts of control of RS

theoretical teaching
Basic concepts, definition of robot system (RS). Orthogonal transformation of coordinates.Rodriguez formula and the transformation matrix (MT), arbitrary and reference configuration of RS.Complex MT of coordinates. Position vectors that define the configuration of the RS, internal and external coordinates of RS. Velocity and acceleration of the center of inertia of an arbitrary robot segment(RSE). Angular velocity and angular acceleration of an arbitrary RSE. Velocity of gripper tip of RS. Direct and

inverse kinematics of robot task-as well as singular cases. Constraints of RS. Momentum, angular momentum, kinetic energy of arbitrary robot segment of RS. Kinetic energy and the metric tensor of RS. Generalized forces and the principle of ideality RS-different cases. Differential equations (DIFE)of motion of RS. (DIFE) of motion of the RS in covariant form. Other methods of forming (DIFE) of motion of RS. DIFE of motion of RS given in the form of kinematic chain with the structure of topological three; DIFE of motion of RS given in the form of closed-kinematic chain. Additional equations of contraints. Constrained motion of robotic gripper. Equations of motion of RS with Langrange multipliers. Redundant RS. Basic concepts of control RS.

practical teaching
Examples of determining the number of degrees of motion of the RS; Calculation the transformation matrix(MT)- in case of Euler angles, and Hamilton-Rodriguez parameters; Determination of kinematic characteristics of the robot segment (RSE): angular velocity and angular acceleration RSE, velocity and acceleration of the observed point-RSE cases of Rezales and Euler angles.Application of Rodriguez transformation matrix, determine position vectors which define the configuration of the RS-in MATLAB environment. Kinematic characteristics of the i-th robot segment. Solving the direct and inverse kinematic task of RS. Determination of (planar) inertia tensor RSE, RS. Obtaining momentum and angular momentum, kinetic energy, the coefficient of the metric tensor RS, generalized forces, Christoffel symbols of the first kind. Solving the direct and inverse dynamics task of the RS. Examples of DIFE of RS simulation in MATLAB-GUI, MATHEMATICA environment, an example of a redundant RS. An example of simulation RS using Cyberbotics Webots package. Example of control of the RS-laboratory robot NeuroArm with 7 degrees of freedom in the MATLAB environment.

prerequisite
desirable courses: Mechanics 1, Mechanics 2 Mechanics 3,

learning resources
1.Čović M. V. Lazarević, Mechanics of Robot, MF Belgrade,2009.(Book)

2.Lazarević M. Exercises in mechanics of robot, MF Belgrade,2006.(ZZD)

3.Wittenburg J., Dynamics of Systems of Rigid Bodies, Teubner, Stuttgart, 1977. (XJ)

4.Craig J., Introduction to Robotics, Mechanics and Control, Addison-Wesley, 1989.

5.Written abstracts from the lectures (Handouts)

6.Cyberbotics Webots - software package

7.NeuroArm-laboratory robot with 7 degrees of freedom.

8.MATLAB,MATHEMATICA-mathematics software packages

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 6
calculation tasks: 5
seminar works: 0
project design: 6
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 30

references
Bruno Siciliano, Oussama Khatib, Springer Handbook of Robotics,Springer-Verlag Berlin Heidelberg 2008.
Thomas R. Kurfess.,Robotics and automation handbook,CRC Press LLC, Boca Raton, Florida,2005
Ahmed A. Shabana, Dynamics of Multibody Systems,Cambridge University Press The Edinburgh Building, Cambridge , UK,2005.
M.W. Spong, M. Vidyasagar: Robot Dynamics and Control (Wiley, New York 1989)
R. Paul: Robot Manipulators: Mathematics, Programming and Control (MIT Press, Cambridge 1982)

Mechatronic robotics

ID: MSc-0827
responsible/holder professor: Lazarević P. Mihailo
teaching professor/s: Lazarević P. Mihailo
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: mechanics

goals
Introduce students to basic concepts of kinematics and dynamics of robotic systems. It is possible to solve direct and inverse kinematics and dynamics of the robot system (RS) using modern theory based on Rodriguez transformation matrix as well as the theory of finite rotations and quaternions. Determination (simulation) models of RS - i.e. differential equations of motion of the RS, which are important in practical problems of the RS.Practical simulations RS using Cyberbotics Webots software package and students work with laboratory robot NEUROARM. Introduce students to the basic control principles of the RS with regard to typical methods and control algorithms of RS.

learning outcomes
• Determine the type of kinematic chain and the number of degrees of freedom of given robotic system (RS)

•Identify and calculate the matrix of transformation, using the orthogonal coordinate transformation and Rodrigo transformation matrix, the theory of finite rotation and quaternions in the case of (Euler angles, Rezal angles, Hamilton-Rodrigues parameters, ...)

• Determine the analytical form basic kinematic characteristics of the RS with a large number of degrees of freedom using Rodrigues approach: characteristic position vectors of RS, speed and acceleration of the center of inertia of the robot segments (RSE), angular velocity and angular acceleration RSE, speed and acceleration of the robot gripper RS at the same time using computer tools (MATLAB, etc.)

• Forming a kinematic model RS with a large number of degrees of freedom in a matrix form and solve direct and inverse kinematics task of RS

• Determine the analytical form of generalized forces which acting on RS

• Forming the differential equations of motion for different cases of RS of topological structure applying Lagrange equations of second kind, the general laws of mechanics, D'Alembert's principle, Langrange-D'Alembert's principle, Žurden principle and the Gauss' principle

• Numerical simulate the previously formed differential equations of motion RS using suitable programming environment (MATLAB, Mathematica, etc.)

• Forming an appropriate RS model in a graphical environment -Cyberbotics Webots with simultaneous simulation of the same

• Compare the existing concepts of control mechanical systems and choose the appropriate concept of control for the considered RS.

theoretical teaching
Basic concepts, definition of robot system (RS). Orthogonal transformation of coordinates.Rodriguez formula and the transformation matrix (MT), arbitrary and reference configuration of RS.Complex MT of coordinates. Position vectors that define the configuration of the RS, internal and external coordinates of RS. Velocity and acceleration of the center of inertia of an arbitrary robot segment(RSE). Angular velocity and angular acceleration of an arbitrary RSE. Velocity of gripper tip of RS. Direct and

inverse kinematics of robot task-as well as singular cases. Constraints of RS. Momentum, angular momentum, kinetic energy of arbitrary robot segment of RS. Kinetic energy and the metric tensor of RS. Generalized forces and the principle of ideality RS-different cases. Differential equations (DIFE)of motion of RS. (DIFE) of motion of the RS in covariant form. Other methods of forming (DIFE) of motion of RS. DIFE of motion of RS given in the form of kinematic chain with the structure of topological three; DIFE of motion of RS given in the form of closed-kinematic chain. Additional equations of contraints. Constrained motion of robotic gripper. Equations of motion of RS with Langrange multipliers. Redundant RS. Basic concepts of control RS.

practical teaching

Examples of determining the number of degrees of motion of the RS; Calculation the transformation matrix(MT)- in case of Euler angles, and Hamilton-Rodriguez parameters; Determination of kinematic characteristics of the robot segment (RSE): angular velocity and angular acceleration RSE, velocity and acceleration of the observed point-RSE cases of Rezales and Euler angles.Application of Rodriguez transformation matrix, determine position vectors which define the configuration of the RS-in MATLAB environment. Kinematic characteristics of the i-th robot segment. Solving the direct and inverse kinematic task of RS. Determination of (planar) inertia tensor RSE, RS. Obtaining momentum and angular momentum, kinetic energy, the coefficient of the metric tensor RS, generalized forces, Christoffel symbols of the first kind. Solving the direct and inverse dynamics task of the RS. Examples of DIFE of RS simulation in MATLAB-GUI, MATHEMATICA environment, an example of a redundant RS. An example of simulation RS using Cyberbotics Webots package.

Simulation examples of RS control using typical methods of control. One example of the control application on the existing laboratory NeuroArm robot with 7 degrees of freedom in the MATLAB environment.

prerequisite

desirable courses: Mechanics 1, Mechanics 2 Mechanics 3,

learning resources

1.Čović M. V. Lazarević, Mechanics of Robot, MF Belgrade,2009.(Book)

2.Lazarević M. Exercises in mechanics of robot, MF Belgrade,2006.(ZZD)

3.Wittenburg J., Dynamics of Systems of Rigid Bodies, Teubner, Stuttgart, 1977. (XJ)

4.Craig J., Introduction to Robotics, Mechanics and Control, Addison-Wesley, 1989.

5.Written abstracts from the lectures,(Handouts)

6.Cyberbotics Webots - software package

7.NeuroArm-laboratory robot with 7 degrees of freedom.

8.MATLAB,MATHEMATICA-mathematics software packages

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 6
calculation tasks: 5
seminar works: 0
project design: 6
consultations: 3

discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 15
final exam: 30
requirements to take the exam (number of points): 35

references

Bruno Siciliano, Oussama Khatib, Springer Handbook of Robotics,Springer-Verlag Berlin Heidelberg 2008.
Thomas R. Kurfess.,Robotics and automation handbook,CRC Press LLC, Boca Raton, Florida,2005
Ahmed A. Shabana, Dynamics of Multibody Systems,Cambridge University Press The Edinburgh Building, Cambridge , UK,2005.
M.W. Spong, M. Vidyasagar: Robot Dynamics and Control (Wiley, New York 1989)
Bruno Siciliano,Lorenzo Sciavicco Luigi Villani, Giuseppe Oriolo, Robotics: Modelling, Planning and Control,2009 Springer-Verlag London

Skill Praxis M - MEH

ID: MSc-1202
responsible/holder professor: Mitrović S. Zoran
teaching professor/s: Buljak V. Vladimir, Gašić M. Vlada, Grbović M. Aleksandar, Zorić D. Nemanja, Jeremić M. Olivera, Lazarević P. Mihailo, Lečić R. Milan, Mandić D. Petar, Milićev S. Snežana, Milošević-Mitić O. Vesna, Mitrović S. Zoran, Mladenović S. Nikola, Obradović M. Aleksandar, Radulović D. Radoslav, Simonović M. Aleksandar, Stevanović D. Nevena, Tomović M. Aleksandar, Trišović R. Nataša, Ćoćić S. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: oral
parent department: mechanics

goals
Practical experience and time spent in an environment where the student realizes his professional career. Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineers in such a business system.

learning outcomes
Student takes practical experience on the organization and functioning of the environment in which student will apply this knowledge in their future professional career. Student recognizes patterns of communication with colleagues and business information flows. Student identifies the core processes in the design, manufacture, maintenance, in the context of his future professional competence. Personal contact and acquaintance are established, which can be used during training, or future employment.

theoretical teaching
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practical teaching
Practical work involves working in organizations which perform a variety of activities related to mechanical engineering. The choice of thematic units and commercial or research organizations is carried out in consultation with the course teacher. Generally, a student may perform in practice: production companies, design and consulting organizations, organizations involved in the maintenance of mechanical equipment, public utility companies and some of the labs at the Faculty of Mechanical Engineering. The practice can also be performed abroad. During practice, students must keep a journal to enter a description of the work performed, the conclusions and observations. After carrying out the practice student must make a report to explain in details mentioned activities to course professor. The report is to be submitted in the form of the paper.

prerequisite
No

learning resources
Resources available on the site of professional practice.

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 0
> auditory exercises: 0
> laboratory exercises: 0
> calculation tasks: 0

seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 90
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 80

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 35

references

Theory of Mechanical Vibrations

ID: MSc-0037
responsible/holder professor: Obradović M. Aleksandar
teaching professor/s: Zorić D. Nemanja, Jeremić M. Olivera, Lazarević P. Mihailo, Mandić D. Petar, Mitrović S. Zoran, Mladenović S. Nikola, Obradović M. Aleksandar, Radulović D. Radoslav, Tomović M. Aleksandar, Trišović R. Nataša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: mechanics

goals
It is necessary to enable the students to independently form and solve linear differential equations of motion of mechanical models of real objects oscillatory moving in different areas of mechanical engineering.

learning outcomes
Upon successful completion of this course, students will be able to:

- Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.
- Form differential equations of motions of small mechanical vibrations of a mechanical system about the equilibrium position in matrix form (determine generalized mass, stiffness and damping matrices, as well as vector of generalized forces transformed on Fourier series).
- Analyze free and forced, as well as damped and undamped linear mechanical vibrations, in a clear observation of phenomena in linear mechanical vibration as well as resonance, beating and the dynamic absorber).
- Calculate (analytical and numerical) quantities which characterize vibration processes: natural frequencies, amplitudes, phase angles, logarithmic decrements and modal matrix.
- Determine equations of motion in analytical form using software (Matlab...) for systems with large number of degrees of freedom.
- Describe free undamped mechanical vibrations of elastic bodies with 1-D mass distribution with appropriate partial differential equations, for cases of longitudinal, torsion and lateral vibrations.
- Numerically solve characteristic equation for various cases of boundary conditions and determine angular frequencies. Determine analytical solutions of appropriate partial differential equations in simpler cases initial and boundary conditions.

theoretical teaching
Stability of equilibrium of the conservative system. Silvester's criteria. Linearization of the differential equations of motion. Vibration of the conservative system. Frequencies. The main mode shapes of vibration. Modal matrix. Conservative systems with special values of natural frequencies (eigenvalues). Vibration of the body on the beam supports. Damped vibration. Forced undamped vibration. Forced vibration. Resonance. Beating. Dynamic amplification factor. The dynamic absorber without damping. Linear oscillations of non-stationary system. Forced damped vibration of the system. Lateral vibration of string. Longitudinal vibration of prismatic bodies. Torsional vibration of the shaft with circular cross section. Lateral vibration of prismatic bodies.

practical teaching
Stability of equilibrium of the conservative system. Silvester's criteria. Linearization of the differential equations of motion. Vibration of the conservative system. Frequencies. The main mode shapes of vibration. Modal matrix. Conservative systems with special values of natural frequencies (eigenvalues). Vibration of the body on the beam supports. Damped vibration. Forced undamped vibration. Forced vibration. Resonance. Beating. Dynamic amplification factor. The dynamic absorber without damping. Linear oscillations of non-stationary system. Forced damped vibration of the system. Lateral vibration of string. Longitudinal vibration of prismatic bodies. Torsional vibration of the shaft with circular cross section. Lateral vibration of prismatic bodies.

prerequisite
None

learning resources
Vuković, J., Obradović,A., Linear vibrations theory of mechanical systems, Mašinski fakultet, Beograd, 2007.,

handouts

Ružić D., Čukić R., Dunjić M., Milovančević M., Anđelić N., Milošević-Mitić V.: Strength of Materials,Book 5, Tables, Mašinski Fakultet, Beograd 2007.

Lazić D., Ristanović M.: Introduction to MATLAB , Mašinski fakultet, Beograd 2005.

MATLAB software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 24
laboratory exercises: 6
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 45
laboratory exercises: 15
calculation tasks: 0
seminar works: 0

project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Rao S.S.: Mechanical vibrations, Addison-Wesley Publishing Company Inc., 1995.
Vujanović B.: Theory of vibrations, Fakultet tehničkih nauka, Novi Sad 1995.
Kojić M., Mićunović M.: Theory of vibrations, Naučna knjiga, Beograd 1991.
Vujičić V.: Theory of vibrations, Naučna knjiga, Beograd 1977.

MOTOR VEHICLES

Automotive friction systems

ID: MSc-0872
responsible/holder professor: Aleksendrić S. Dragan
teaching professor/s: Aleksendrić S. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
Course objective is to provide an understanding and develop students' skills and knowledge in the area of design, development, and maintenance process of the friction based vehicle systems such as clutch, braking systems,and friction materials.

learning outcomes
Course outcomes are development of student's abilities to: a) understand requirements being imposed to automotive vehicle systems, b) be able to design, calculate and testing of the motor vehicles braking systems, c) be able to design, calculate and testing of the vehicle main clutches, d) be able to understand and design the automotive brakes and clutches friction material characteristics, e) be able to maintain the friction based vehicle systems.

theoretical teaching
Theoretical lectures are divided into 7 sections:

1)Introduction – Friction based vehicle systems.

2)Clutch – design, calculation and testing.

3)Braking systems- Introduction

4)Characteristics of vehicle braking systems

5)Design and calculation of vehicle braking systems

6)Characteristics of clucth and brake friction materials.

7)Maintenance of clutch and braking systems- Introduction.

practical teaching
Students carry an engineering project. Project is related to the following tasks:

1)Calculation of the main friction clutch.

2)Calculation of a passenger car braking system.

3)Calculation of a braking system with the pneumatic transmission.

4)Calculation of a braking system with the air over hydraulic transmission.

5)Calculation of trailer/semi-trailer braking system.

prerequisite
There is no precondition.

learning resources
1. J. Todorović, Braking of motor vehicles, Faculty of Mechanical Engineering, 1989.

2. D. Aleksendrić, Hand-outs, 2015.

3. D. Aleksendrić, V. Ćirović, Intelligent braking, Faculty of Mechanical Engineering University of Belgrade (in press), 2015.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Savaresi S., Taneli M. Active Braking Control Systems Design for Vehicles, Springer 2010.
Aleksendric D., Carlone P. Soft Computing in the design and manufacturing of composite materials, Elsevier-Woodhead Publishing, 2015.

Conformity, compliance and product warranty

ID: MSc-1335
responsible/holder professor: Vasić M. Branko
teaching professor/s: Vasić M. Branko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals

Course objectives include the achievement of competencies and academic and professional knowledge and skills, as well as methods for their acquisition, in areas that include the Conformity of products (machinery, vehicles, equipment) or services and its Compliance, and all that relates to the product Warranty.

The goals derive from the basic tasks. They determine the concrete results that should be achieved within the course and represent the basis for the control of the achieved results.

learning outcomes

Upon successful completion of this course, students should be encouraged to:

- terminologically, essentially and through examples define Conformity, Compliance and Warranty;

- explain the concepts and applications of methods that measure product user Satisfaction;

- implement ISO 10002 in each organization and define and document Guidelines for dealing with complaints and reclamations;

- in the imaginary (given) company define the necessary and permitted Advertising and Pre-contractual information about the products (or services) of the company, to define and document the Warranty and Conformity, Product Liability, content and graphics of the Warranty Certificate and Technical Instructions for yse and мaintenance products (elimination of small and large discrepancies);

- form the Book of Complaints, ie define electronic databases and the appropriate information system for managing complaints.

theoretical teaching

The content of the subject includes theoretical and practical teaching.

The entire teaching is divided into five blocks, each of which in theoretical teaching consists of four thematic units with a total fund of 20 hours, while in the part of practical teaching the same four blocks are realized within 15 hours of exercises and 15 hours of independent student work.

There are 15 hours for knowledge tests, of which 10 for partial knowledge tests and 5 for the final knowledge test.

The five basic teaching blocks cover the following areas:

(a) Introduction, legislation, literature;

(b) Practical solutions, case studies of companies in Serbia;

(c) Development of joint and separate models and simulations on models;

(d) Information systems, software and applications;

(v) Risk identification and risk management, ISO 10002, ISO 9001 and other standards.

practical teaching
The content of the course includes theoretical and practical teaching.

The entire course is divided into five blocks - classroom exercises follow the lectures.

Practical classes are realized through 15 hours of exercises and 15 hours of independent student work (assignments, seminar papers and final project).

A total of 15 hours are scheduled for knowledge tests, of which 10 for partial knowledge tests and 5 for the final knowledge test.

The five basic teaching blocks cover the following areas:

(a) Introduction, legislation, literature;

(b) Practical solutions, case studies of companies in Serbia;

(c) Development of joint and own models and simulation on models;

(d) Information systems, software and applications;

(v) Risk identification and risk management, ISO 10002, ISO 9001 and other standards.

prerequisite
Defined by study program / module curricula.

learning resources
Students who choose this subject receive both books listed in the literature free of charge from the teacher;

Students receive the third book in electronic form (CD edition of the Faculty of Mechanical Engineering);

Students receive a laptop for use throughout the semester, until the defense of the project, ie taking the exam;

Students receive software and a mobile phone application, which is used to create a project, and which is "in the cloud", so they can access it from anywhere 24 hours a day;

1. Vasić, B: Management and Engineering in Maintenance, Institute for Research and Design in Economy, Belgrade, 2006

2. Vasić, M; Васић, Б: Compliance, Conformity, Warranties and Product Liability, UKAS - Association for Quality, Accreditation and Standardization, Belgrade, 2020

number of hours: 75

active teaching (theoretical): 25
lectures: 15
elaboration and examples (revision): 10

active teaching (practical): 25
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 5
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 25
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 15
seminar works: 15
project design: 30
final exam: 30
requirements to take the exam (number of points): 40

references

Forensic Engineering

ID: MSc-0876
responsible/holder professor: Popović M. Vladimir
teaching professor/s: Popović M. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
Student is enabled to apply forensic engineering methods, particularly in the area of motor vehicles, which comprises analyses and reconstruction of road accidents, vehicle damage estimation and vehicle value estimation based on case study principles. Analogous methods will be applied in other field of mechanical engineering, depending on the interest of students.

learning outcomes
Upon successful completion of this course, students should be able to:

- explain the concept of forensics and forensic engineering, with respect to vehicles;

- define and analyse technical system failures, their causes and effects, with a special emphasis on the application in automotive field;

- identify and analyze the causes of traffic accidents in which vehicles participated, with elements of investigation and reconstruction;

- make estimate of the damages on the vehicle and its value, on the case study principles;

- define the technology of the damages assessment and the cost of revitalization (repair) of the vehicle/system;

- analyze adequate technical solutions and conditions under which accidents might be avoided.

theoretical teaching
Organized in blocks.

First Block: general knowledge of forensics and forensic engineering, i.e. technical systems failure analyses, their causes and consequences, with a particular emphasis on the area of automotive engineering.

Second Block: Vehicle condition changes and value estimation methods

Third Block: Vehicle and component failures, i.e. accidents causing vehicle damage

Fourth Block: Vehicle damage estimation techniques and repair costs

Fifth Block: Analyses of road vehicle accident causes and consequences, with the elements of accident site investigation and evidence collection, including accident reconstruction.

practical teaching
Organized in two forms, as listening exercises aiming to enable preparation for working on case studies and in the form of seminar assignments within which each student will individually resolve the subject relevant cases on the basis of case study methodologies. Student are provided with real data about vehicle (or other technical systems of interest) accidents, and they will study the causes and the consequences of such accidents or the causes of damage of these systems, in particular they will analyze why an accident happened and what possibilities there are to avoid it. A particular attention will be payed to estimation of conditions under which such an accident might be generally avoided, but also in the particular case.

prerequisite
No special requirements.

learning resources
1. Class room

2. Other author book

3. Foreign language books

4. Other literature

5. IT Hardware

6. IT software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 10
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 60

references
Lecturing handouts
Randall K. Noon, Forensic Engineering Investigation, CRC Press, 2001, ISBN 0849309115
Wolfgang Hugemann, Unfall-rekonstruktion, Authoren Team GbR, 2007, ISBN 3000194193
R.M. Brach, Vehicle Accident Analysis and Reconstruction Methods, SAE Intl., 2005, ISBN 0768007763
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Intelligent vehicle systems

ID: MSc-0713
responsible/holder professor: Aleksendrić S. Dragan
teaching professor/s: Aleksendrić S. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
The goal of intelligent vehicles and accordingly intelligent vehicle systems is to augment vehicle autonomous driving either entirely or partly for the purposes of safety, comfortability, and saving energy. The tasks of intelligent vehicles become more challenging due to dynamic change of complex environment perception and necessity for sensing, modeling and prediction of different influencing factors on the vehicle performance. Autonomous intelligent vehicles have to perceiving and modeling environment in order to control the vehicles. The vehicle motion control faces the challenges of strong nonlinear characteristics due to high mass, especially in the processes of high speed and sudden steering/braking. It needs processing, modelling and prediction non-linear chnages in the vehicles system operation based on large amounts of data from multi-sensors and complex dynamic changes in an environment. Course objective is to provide an understanding the design and development process of intelligent vehicle systems and to develop students' skills and knowledge in the area of intelligent vehicle systems development.

learning outcomes
Course outcomes are development of student's abilities to: a) understand requirements being imposed to intelligent vehicle and its systems, assemblies, sub – assemblies, and parts, b) analyze the vehicle system operation and understand influences of the new intelligent solutions in the vehicle systems design on the vehicle overall performance and quality of use c) application of artificial intelligence techniques in development of intelligent solutions of the vehicle systems, d) analyze, understand and reconcile the new intelligent solutions in the vehicle system operation with legislation related to the specific vehicle systems and sub systems.

theoretical teaching
Theoretical lectures are divided into 7 sections:

1)Introduction – Intelligent vehicles and intelligent transport.

2)Monitoring and modeling of tire –road interaction.

3)Intelligent vehicle longitudinal control.

4)Intelligent vehicle lateral control.

5)Intelligent vehicle vertical control.

6)Intelligent vehicle vision systems.

7)Integrated intelligent control.

practical teaching
Students carry out a group-engineering project. Project is related to introduction of intelligent solutions in the given vehicle system operation. Students have to:

1)critical analyze the design solutions of the given vehicle system.

2)identify possibilities for introduction of the system intelligent abilities.

3)model and predict the system performance based on artificial intelligence techniques

4)test the system intelligent solutions.

5)compare conventional and introduced intelligent system performance.

prerequisite
There is no precondition.

learning resources
D. Aleksendrić, Intelligent vehicle systems, (hand-out), 2015.

D. Aleksendrić, V. Ćirović, Intelligent braking (book-in press), 2015.

Z. Miljković, D. Aleksendrić, Artificial neural networks-solved examples with theoretical background, Faculty of Mechanical Engineering University of Belgrade, 2009.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 30

references
H. Chneg: Autonomous intelligent vehicles - Theory, Algorithms, and Implementation , Springer 2011.
L. Li, F.-Y. Wang: Advanced Motion control and Sensing for Intelligent vehicles , Springer 2007.
R. Bishop: Intelligent vehicle technology and trends, © 2005 ARTECH HOUSE, INC.

Maintenance of Machinery and Equipment

ID: MSc-1141
responsible/holder professor: Vasić M. Branko
teaching professor/s: Vasić M. Branko, Popović M. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: motor vehicles

goals
Managing Machine and Equipment Maintenance as part of Asset Management (Asset Management) is a systematic process of planning, maintaining and operating viable physical assets during their useful (economic) lifetime, in order to achieve current and future optimal benefits for all stakeholders in the community.

The effective management of assets is becoming increasingly important to organizations and their interested parties. In order to share the latest thinking, processes, methods and tools in joined up management of any types of asset, this comprehensive one semester course provides techniques and methods for students to explore the organizational implications of the:

International standard for Asset Management with focus on:

- What is Asset management and why it is important to an organization
- The benefits of a management system for asset management
- The key terms, concepts and principles of ISO 55001:2014
- The main requirements of ISO 55001:2014
- Maintenance KPI Key Performance Indicators

Then, with the system of the indicators with focus on:

- economical, technical and organisational
- Methodology for selection and use of key performance indicators for maintenance

and project management and organization of the maintenance system, through:

- An Overview of Key Project Management Concept
- Initiating the Project
- Identifying the Work
- Estimating the Work
- Scheduling the Work
- Creating the Budget

learning outcomes
Upon this comprehensive one semester course, students will be able to:

- Recognize and be able to apply asset management terminology, definitions and principles
- Identify and manage the expectations of stakeholders with respect to asset management
- Become familiar with internationally recognized asset management methodologies and good practices

- Apply structured approaches available for the improvement of valye realization from assets
- Recognize the valye obtainable from the integrated approach to the life cycle and risk-based management of assets
- Understand what Maintenance is doing
- How maintenance should be measured
- What maintenance is achieving for the business and
- What more it can do to improve operational performance
- Ensure that projects are set-yp for success from the start
- Understand the role of the project manager, business analyst, and others in managing projects
- Develop an integrated project plan inclyding realistic scope, schedules, budgets, and risks
- Learn how to effectively track and report on project progress

theoretical teaching

Theoretical part of the course is divided into four blocks, consisting of four thematic ynits with a total fond of 4 x 5 = 20 h, 4 h 2,5 = 10 hrs to develop the lecture and master the new material.

The basic teaching blocks include the following areas:

- Asset Management concept and requirements of international standards,
- Machinery maintenance strategies as a key asset management segment,
- Basics of project management,
- Key performance maintenance indicators

practical teaching

The course content also includes practical lessons. The entire class is divided into four blocks - auditory classes are followed by lectures. Practical classes are realized through 15 hoyrs of exercises and 15 hoyrs of independent stydent work (compyting tasks and seminar work). A total of 15 hoyrs are foreseen for checking knowledge, oyt of which 10 for partial knowledge tests and 5 for final examination of knowledge. The four basic teachers include the following areas:

- Asset Management concept and requirements of international standards,
- Machinery maintenance strategies as a key asset management segment,
- Basics of project management,
- Key performance maintenance indicators.

prerequisite

Defined by curriculum of module for motor vehicles.

learning resources

1. Vasic B., Todorovic J., et al.: Maintenance of Technical Systems, Institute for Research and Design in Commerce & Industry, Belgrade, 2006. (KPN)

2. Vasic B.: Management and engineering in maintenance, Institute for research and design in commerce and industrym Belgradem 2006.

3. Vasic B., Popovic B.: Engineering management methods, Institute for research and design in commerce and industrym Belgradem 2007.

4. Vasic, M., Stanojevic, D., Todorovic M., Dimitrijevic, M., Stanojevic, N. (2016): Maintenance management according to the best European practice, Serbian Maintenance Society, ISBN 978-86-84231-44-6

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 5
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 7
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 25
seminar works: 35
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references
1. Vasic B., Todorovic J., et al.: Maintenance of Technical Systems, Institute for Research and Design in Commerce & Industry, Belgrade, 2006. (KPN)
2. Vasic B.: Management and engineering in maintenance, Institute for research and design in commerce and industrym Belgradem 2006.
3. Vasic B., Popovic B.: Engineering management methods, Institute for research and design in commerce and industrym Belgradem 2007.
4. Vasic, M., Stanojevic, D., Todorovic M., Dimitrijevic, M., Stanojevic, N. (2016): Maintenance management according to the best European practice, Serbian Maintenance Society, ISBN 978-86-84231-44-6

Skill Praxis M - MOV

ID: MSc-1224
responsible/holder professor: Rakićević B. Branislav
teaching professor/s: Aleksendrić S. Dragan, Blagojević A. Ivan, Vasić M. Branko, Mitić R. Saša, Popović M. Vladimir, Rakićević B. Branislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: motor vehicles

goals
Aim of praxis is to introduce procedures and processes in production of vehicles and their components to students, and also specific activities related to development and production, testing, exploitation and maintenance of vehicles and their systems.

learning outcomes
With this praxis, students in particular conditions (vehicle production, maintenance, testing and exploitation), achieve practical view on production of elements, components and vehicle systems, as well as on problems of vehicle completion, exploitation and maintenance, according to the plan and the program of practice.

theoretical teaching
No theoretical classes.

practical teaching
Students autonomously choose companies to complete the praxis in. Students' activities are performed according to guidelines and instructions on how to behave and on the subjects of interests during the stay in particular company, and also on how to write the praxis diary.

prerequisite
No special requirements.

learning resources
Instructions for writing the praxis diary.

number of hours: 90

active teaching (theoretical): 0
lectures: 0
elaboration and examples (revision): 0

active teaching (practical): 80
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 80
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 8
check and assessment of projects: 0

colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 60
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references
All available literature from courses from Motor Vehicle Department.

System Effectiveness

ID: MSc-0711
responsible/holder professor: Vasić M. Branko
teaching professor/s: Blagojević A. Ivan, Vasić M. Branko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: motor vehicles

goals
The objectives of the course are to provide a comprehensive insight into the issues (analysis and design) of system effectiveness, primarily in the areas of reliability and availability of technical systems (vehicles).

learning outcomes
Upon successful completion of this course, students should be able to:

- Explain the concepts of system effectiveness, reliability and failure;
- Analyze the obtained failure time data;
- Apply of the basic laws of probability and statistics to calculate the reliability;
- Obtain theoretical probability density and reliability function based on empirical data on failures of the elements;
- Determine the reliability of a complex system based on the reliability of the elements that form a complex system;
- To form fault tree of technical system and analyze it;
- To design machine elements on the basis of reliability.

theoretical teaching
Defining the requirements for effectiveness and reliability and availability of system elements and system. The system. The basis of probability theory and statistics and its application in analysis and design of reliability. Definition of failure of the elements and system. Determination of empirical and theoretical characteristics of reliability of the elements of a system and of the systems (histogram, polygon, intensity of failure, the function of frequency, mean value, distribution laws (Weibull, normal, exponential, binomial, Poisson), tests of trust, confidence interval). Determination of reliability block diagrams of simple and complex systems (vehicles) with the application of probability theory of complex events. Fault tree analysis, the analysis of mode, effect and criticality of faults, integrated system approach. Design of vehicle elements for a given level of reliability, relations of workload and critical load, the selection of intensity of failures for specific working conditions and environment.

practical teaching
The event-failure. Basics of probability theory and statistics. Determination of empirical and theoretical characteristics of reliability of the elements of a system and of the systems (histogram, polygon, intensity of failure, the function of frequency, mean value, distribution laws (Weibull). The compound probability. Reliability block diagram - connection of the elements in the system. Determining the function of system reliability (simple and complex). Design of reliability. Design based on work and critical loads. Allocation of reliability. Fault tree analysis, analysis methods, effects and criticality of failures.

1. Examples.

2. Examples - Independent work.

prerequisite
No previous preconditions.

learning resources

1. J. Todorovic, B. Vasic: System Effectiveness, Faculty of Mechanical Engineering, Belgrade 1991.
2. B. Vasic, N. Stanojevic: Integrated Cost-Benefit and Multi-Criteria Analyses Based on the Principles of Life Cycle Engineering, MIRCE Science Limited, UK, 2007.
3. B. Vasic, V. Popovic: Engineering management metods, Institute for research and design in comerce & industry, Belgrade, 2007.
4. Vasic, B. : Management and Engineering in Maintenance, IIPP, 2004.
5. G. Ivanovic, D. Stanivukovic, I. Beker: Reliability of Technical Systems, Faculty of Technical Sciences, Novi Sad, 2010.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 15
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 8
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 30
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

1. J. Todorovic, B. Vasic: System Effectiveness, Faculty of Mechanical Engineering, Belgrade 1991.
2. Б. Васић, Н. Станојевић: Integrated Cost-Benefit and Multi-Criteria Analyses Based on the Principles of Life Cycle Engineering, MIRCE Science Limited, UK, 2007.
3. B. Vasic, V. Popovic: Engineering management metods, Institute for research and design in comerce & industry, Belgrade, 2007.
Vasic, B. : Management and Engineering in Maintenance, IIPP, 2004.
5. G. Ivanovic, D. Stanivukovic, I. Beker: Reliability of Technical Systems, Faculty of Technical Sciences, Novi Sad, 2010.

Vehicle body structure

ID: MSc-0441
responsible/holder professor: Rakićević B. Branislav
teaching professor/s: Mitić R. Saša, Rakićević B. Branislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: motor vehicles

goals
Aims of this course include achieving the competences to conquer specific knowledge and skills needed for overwiewing and understanding problems related to construction, calculation, testing and verification of support structures of different categories of vehicles.

learning outcomes
After successful completition of this course, students should be trained to:

- Know and explain basic methods and procedures for vehicle's body behaviour identification;

- List and explain characteristic calculation regimes specificities in body calculation;

- Recognize and explain the problems of thin-walled open cross-sections;

- Identify and interpret basic postulates of UN Regulations regarding the strength of bus superstructures;

- Analyze and explain basic problems of strength related to chassis – body interaction;

- Categorize different body types regarding their torsion stiffness and propose the application of appropriate elements for connection;

- Define all aspects needed for completition of commercial vehicles, taking into account related bodybuilder instructions.

theoretical teaching
(1) Introduction: Constructive concepts of superstructures in accordance with vehicle classification and categorization, characteristic solutions, basic instructions and recommendations; (2) Identification of superstructure behaviour, testing/calculation; methods, parameters and approval criteria; behaviour optimization, characteristic calculations modes; (3) Behaviour specificity of thin-walled open elements of SS; (4) Method of common constructive support surfaces, basic types of superstructures, ways and possibilities for implementation; (5) Finite elements method (FEM) in terms of methodological approach for identification of superstructure behaviour, basic characteristics and specificities; (6) Bus superstructures; specifities, strength of superstructures, domestic and international regulations; (7) Commercial vehicles superstructures; constructive and technological specificities of chassis of commercial vehicles, superstructures (different types, connection types for chassis and superstructure connecting, instructions and recommendations of chassis manufacturers), problems of vehicle completion (requests of valid standards and regulations, aspects of calculation, testing and verification); (8) Passenger vehicles superstructures; crash problems, values related to crashes, possibilities of modelling and experimental verification; (9) Regulations related to vehicle behaviour during crash (UN Regulations, EURO NCAP tests), characteristic parameters and criteria.

practical teaching
(1) Review of characteristic examples of passenger vehicles superstructures; (2) Review of specificities of superstructures for different bus categories (low-floor city bus, high floor touristic bus...); (3) Review and comments on chassis examples for commercial vehicles, as well as instructions and

recommendations of manufacturers for superstructure mounting; (4) Examples of implementation of analytical approach in chassis calculation (ladder-type chassis); (5) Review of problems in calculation using FEM for particularly characteristic examples; (6) Bus superstructures; valid regulations (UN Regulations), requests related to passive safety (UN Regulation No. 66, review, comments and ways for fulfilling all requirements); (7) Individual student thesis related to bus superstructures; (8) Commercial vehicles superstructures; valid regulations (UN Regulations), requests related to passive safety (UN Regulation No. 58, 73,...); (9) Review of construction of some specific superstructures, explanations for different types of connections between chassis and superstructure and their implementation in process of vehicle completing; (10) Comments for possibilites to special purpose vehicles realization and explanations for implementation of instructions and recommendations of chassis manufacturers; procedures for definning the relevant safety and technical characteristics of completed vehicles; (11) Individual student thesis related to special purpose commercial vehicles (different superstructures); (12) Passenger vehicles superstructures; regulations related to vehicle behaviour during crash (UN Regulations, EURO NCAP tests), comments related to characteristic examples.

prerequisite
No special requirements.

learning resources
1. N. Janicijevic, D. Jankovic, J. Todorovic: Design of Motor Vehicles, Faculty of Mechanical Engineering, Belgrade, 2000,

2. D. Jankovic, N. Janicijevic: Coupling Road Vehicles and Special Devices: Theory – Design – Calculation – Standards, Faculty of Mechanical Engineering, Belgrade, 1985,

3. D. Jankovic, J. Todorovic, G. Ivanovic, B. Rakicevic: Theory of Vehicle Motion, Faculty of Mechanical Engineering, Belgrade, 2001,

4. Handouts,

5. Laboratory for Motor Vehicles, Institute for Motor Vehicles,

6. Laboratory CIAH, Institute for Motor Vehicles,

7. National and international standards, UN Regulations, EC Directives, related to motor vehicles

8. Technical documentation from leading world manufacturers (Volvo, Mercedes, Iveco, Renault, etc.) – Characteristics of vehicle chassis / guidlines and instructions for bodybuilders and vehicle completing,

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 8
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0

check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 36

references

Tasko Maneski: Computer Modelling and structure calculation, Faculty of Mechanical Engineering, Belgrade, 1998.
Julian Happian-Smith: An Introduction to Modern Vehicle Design, Butterworth-Heinemann, 2002.
Dobrosav Ruzic: Strength of Constructions, Faculty of Mechanical Engineering, Belgrade, 1995.
M. Huang, Vehicle Crash Mechanics, CRC Press, 2002.

Vehicle design

ID: MSc-1333
responsible/holder professor: Blagojević A. Ivan
teaching professor/s: Blagojević A. Ivan, Mitić R. Saša, Rakićević B. Branislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: motor vehicles

goals
The goal of the course is to develop the logic of designing the vehicle systems and assemblies, based on the requirements and legal regulations the vehicle has to be in compliance with. Apart from that, assembling the systems into a functional unit that represents the vehicle poses a skill a student shall acquire, while respecting the weight, dimensional and ergonomic limits. Gaining the practical experience in computer aided design, as well as the analysis of different solutions, forms the integral part of the aforementioned process.

learning outcomes
Upon successful completion of this course students should be able to: identify all the requirements that a system to be designed and later exploited shall meet; analyze the existing solutions of vehicle systems and assemblies to be used or modified for a different vehicle; deduce the load the vehicle assembly is exposed to; apply acquired logic through an independent design of an adequate system for a given project; use modern engineering tools.

theoretical teaching
The lectures consist of three units. The first unit encompasses vehicle layout, weight and dimensions of a vehicle, as well as legal requirements regarding the vehicle layout. This unit considers the vehicle ergonomics as well. The second unit encompasses power transmission with a special attention paid to gearbox and driven axle design. The third unit encompasses suspension and steering systems, meaning the system components and the parameters that define their kinematics and load. Each unit implies the definition of: initial requirements and parameters the design is based on; adoption of the adequate concept; analysis of existing solutions, identification of adequate system or assembly elements and their positioning and dimensioning; kinematics and basic load analysis the structure is exposed to.

practical teaching
The practical coursework consists of creating a project for each of the aforementioned units. The showpieces of systems, assemblies and vehicles aid the students in completing the coursework, as well as adequate software tools.

prerequisite
No special requirements.

learning resources
Computers with adequate software tools, showpieces of systems, assemblies and vehicles, as well as their digital illustrations.

number of hours: 75

active teaching (theoretical): 30
lectures: 25
elaboration and examples (revision): 5

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 0

calculation tasks: 0
seminar works: 0
project design: 20
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 3
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 40

references
Rakicevic B.: handouts
Mitic S.: handouts
Blagojevic I.: Suspension and steering system design - handouts

Vehicle Maintenance

ID: MSc-0875
responsible/holder professor: Vasić M. Branko
teaching professor/s: Vasić M. Branko, Popović M. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
Student acquires relevant theoretical and practical knowledge about after sales activities of a vehicle manufacturer, and in particular concerning vehicle maintenance and the ways of establishing a system of authorized service organizations taking into consideration that without application of an appropriate maintenance system there will be no normal vehicle operation nor vehicle usage.

An automotive engineer must know how to make a vehicle, but also how to use and maintain it in order to enable its mission to be fulfilled in all usage conditions.

An automotive engineer must be educated and trained to design so called "Vehicle Maintenance System" i.e. to design programs and plan of preventive, corrective and combined maintenance as well as to design vehicle service technology and facilities in which it can be applied.

learning outcomes
Upon successful completion of this course, students should be able to:

-Explain the processes of technical maintenance of different motor vehicle types and categories;

-Do analysis of state changes of motor vehicles and identification of their causes (state changes due to the wrong using in vehicle exploitation, state changes due to the fatigue and wear, state changes due to the wrong maintenance of vehicle;

-Organize and implement different concepts and methodologies of vehicle maintenance;

-Determine necessary logistic and system support during vehicle maintenance (management of: spare parts, human resources, vehicles upon receipt in services (which depends of planned operations etc.));

-Solve practical problems regarding to the processes of vehicle maintenance;

-Recognize key performance indicators of maintenance;

-Design service for vehicle maintenance according to the planned maintenance operations and types and categories of vehicle which will be maintenance in that service, through determination of the following parameters: production program, number of workers and work places, number and types of service work spaces;

-Determine the technical equipment for designed vehicle service (diagnostic systems, tools etc.);

theoretical teaching
Theoretical tuition is composed of four blocks each of them containing four thematic units with an overall number of 4x5 = 20 lecturing hours, with 4 x 2,5 = 10 additional hours for working out on the teaching subjects and acquisition of new material.

Four basic theoretical tuition blocks contains (a)Maintenance - Life cycle, and investment effectiveness, Condition Time Sequence, Maintenance technological backgrounds, Variation of technological solutions, usage and maintenance in specific conditions, (b) Maintenance technologies (corrective, preventive, combined), Vehicle condition changes, Vehicle condition estimation methods, Technological procedures, (c) Project assignment, Number of vehicles to maintenance, Estimation of maintenance system capacity, Quality of Service, and (d) Kinds of maintenance technology processes, Maintenance Work place, Information systems, Logistics, Standardized and specialized service facilities.

practical teaching
In the practical tuition part student has 30 hours of individual work to work out a seminar work and a project.

In the practical tuition part, following the aforementioned four main blocks, student works out more detailed thematic evaluation within the listening exercises followed by an individual seminar assignment about designing maintenance system for a given vehicle and an individual project assignment about maintenance system for a given service facility based on the knowledge acquired within the third and the fourth block. Student will also work out on a assignment considering maintenance logistics support as an integral part of the maintenance system, will deal with the selection and choice of garage equipment for a given work place, and will also deal with the dimensioning of maintenance capacities, in addition to some basic elements concerning an information system about operation and service of vehicles, and maintenance system specification.

prerequisite
A B.Sc. diploma in automotive engineering is preference, and already passed exams in "Vehicle design 1" and "Vehicle design" are a must.

learning resources

1. Class room

2. Subject teacher's book

3. Subject teacher's book

4. other literature type

5. IT Hardware

6. IT software

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 10
consultations: 3
discussion and workshop: 2
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 30

references

Vasic B., Jankovic D., Curovic, D.: Technology for vehicle maintenance, Faculty of Mechanical Engineering, Belgrade, 2000.

Vehicle Mechatronics

ID: MSc-0873
responsible/holder professor: Popović M. Vladimir
teaching professor/s: Vasić M. Branko, Popović M. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
Course objectives are designed to meet the needs of the 21st century automotive industry for graduate students with the necessary skills and understanding in mechatronics. Students should be able to deal with a wide range of activities that include research, design, development and testing of mechatronic systems in motor vehicles.

learning outcomes
Upon successful completion of this course, students should be able to:

- explain the concept of mechatronics and mechatronic systems, with respect to vehicles;

- describe in a nutshell the function of all components of vehicle mechatronic systems;

- analyse and explain the specificities of vehicle mechatronic systems (suspension systems, braking systems, power transmission systems, steering systems, integrated systems);

- analyze the problems when designing a vehicle mechatronic system;

- define the design process of a vehicle mechatronic systems (which includes the determination of future system goal and development of a functional mechatronic system scheme);

- simulate the operation of the designed mechatronic system, as well as to define the testing method for the system in question.

theoretical teaching
Theoretical part of the course comprises following units: introduction to mechatronics, sensors and actuators, anti-lock braking systems, stability control systems, steer-by-wire steering systems, active suspension systems, advanced driver-assistance systems (parts 1, 2 and 3).

practical teaching
Practical part of the course is focused on students's own mechatronic system project.

prerequisite
No special requirements.

learning resources
Handouts in digital form.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 30
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 30
> auditory exercises: 10
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 0

project design: 20
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 35
requirements to take the exam (number of points): 35

references
Handouts in digital form

Vehicle Propulsion and Suspension Systems

ID: MSc-1334
responsible/holder professor: Mitić R. Saša
teaching professor/s: Blagojević A. Ivan, Mitić R. Saša, Rakićević B. Branislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: motor vehicles

goals
Mastering the knowledge and skills necessary to perceive and understand the problems related to the design and calculation of vehicle transmission, suspension system and steering system and their impact on the characteristics and behavior of the vehicle.

learning outcomes
Upon successful completion of this course, students should be able to:

Explain the process of calculation of transmission, suspension system and steering system; Perform calculation of transmission, suspension system and steering system; Analyze the possibilities of predicting the impact of newly designed solutions of propulsion and suspension systems on the performance of the vehicle; Use modern engineering tools; Apply acquired logic through an independent calculation of an adequate system for a given project.

theoretical teaching
Theoretical part of course consist of the following units: Design and calculation of transmission systems; Design and calculation of hydrodynamic and hydrostatic transmissions; Functional-constructive characteristics of suspension system and wheels; Characteristic performances and their specifics; The influence of suspension system and wheels on the longitudinal, lateral and vertical dynamics of the vehicle; Kinematic-geometric characteristics of suspension and steering system and its influence on the distribution of the relevant forces and vehicle behavior.

practical teaching
Practical part of course consist of individual projects for all of the aforementioned units. Wherever feasible, individual projects are done on a computer, using appropriate software.

prerequisite
No special requirements.

learning resources
Computers with appropriate software tools, showpieces of systems, assemblies and vehicles, as well as their digital illustrations.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 25
> elaboration and examples (revision): 5
>
> **active teaching (practical):** 30
> auditory exercises: 5
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 0
> project design: 20
> consultations: 5

discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 3
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 40

references

Mitic S.: handouts
Rakicevic B.: handouts
Blagojevic I.: Suspension and steering system design - handouts

Vehicle Testing

ID: MSc-1143
responsible/holder professor: Popović M. Vladimir
teaching professor/s: Popović M. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
The main objective of this course is to enable students to obtain objective information on the quality and performance of vehicles and their assemblies and parts at different stages of development, production and exploitation of vehicles using a series of procedures.

learning outcomes
Upon successful completion of this course, students should be able to: 1. Explain how to measure physical quantities electrically while testing motor vehicles; 2. Select transducers and sensors, amplifiers, supplementary and auxiliary devices and devices for displaying vehicle test results; 3. Conduct different vehicle tests; 4. Analyze test results.

theoretical teaching
Theoretical classes are focused on the following areas: basic concepts of vehicle testing; measurement of physical quantities by electrical means (basic characteristics of transducers and sensors used for testing in the field of motor vehicles, measuring instruments, supplementary and auxiliary devices and devices for displaying test results); strain gauges.

practical teaching
Practical classes consist of the following laboratory exercises: testing by simulation in CarSim software; testing of completed vehicles; testing of vehicles for transport of perishable foodstuffs; testing of vehicles for transport of dangerous goods; testing of ambulance vehicles; testing of protective structures of agricultural tractors; testing of pedestrian warning sound system for installation on electric vehicles; measurement of chassis torsional rigidity, burning behavior of vehicle interior materials, noise measurement.

prerequisite
No special requirements.

learning resources
Handouts in digital form.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 30
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 30
> auditory exercises: 0
> laboratory exercises: 25
> calculation tasks: 0
> seminar works: 0
> project design: 5
> consultations: 0
> discussion and workshop: 0
> research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references
Handouts in digital form

Vehicles and Environment

ID: MSc-0874
responsible/holder professor: Blagojević A. Ivan
teaching professor/s: Blagojević A. Ivan, Mitić R. Saša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: motor vehicles

goals
The goal of this subject is to give the students an insight into effects vehicles have on the environment. Preservation of the environment and minimization of the negative impacts of driver-vehicle-environment system are the basis of modern vehicle development and exploitation. Therefore a more detailed analysis of these effects in this case are a prerequisite for creating a modern engineer, not only in the field of motor vehicles.

learning outcomes
Upon successful completion of this course, students should be able to:

- Explain the concept of fuel consumption and the possibilities for its reduction;

- Analyze the impacts of driver on fuel consumption;

- Identify and explain the harmful elements of the exhaust emissions of motor vehicles, ways of their formation and effects, methods of measurement and legal constrain values per component;

- Identify alternative vehicle drives and fuels;

- Analyze working principles of hybrid and electric vehicles;

- Explain the impact of noise and vibration produced by vehicle;

- Recognize environmentally friendly and modern materials used in the design and manufacture of vehicles;

- Describe the recycling process and the life cycle of the vehicle.

theoretical teaching
Introductory classes relate to the importance of the vehicle in production, transportation and traffic in contemporary economic and social environment.

They are followed by lectures that look back on the development of automotive technology that was largely affected by environmental conditions. The following lectures are divided into blocks according to a rough classification of basic elements of the impact of vehicles and drivers on the environment:

1. fuel consumption; 2. exhaust emission; 3. hybrid and electric vehicle drivetrain; 4. alternative fuels; 5. noise and vibration; 6. recycling and the use of modern materials.

The final lectures are planned to present the future trends in the design and exploitation of vehicles with the aim of improving environmental protection.

practical teaching
By conducting the practical training, students should identify and analyze the impact of the vehicle-driver-environment system on the environment, primarily through fuel consumption and exhaust emission. Through the laboratory classes, parameters of the vehicle engine for different driving modes (speed, acceleration and road conditions) are aquisited, providing the data for students to process in their reports and draw the conclusions.

In addition, students explore operating modes of hybrid and electric vehicles and effects of their.

Students are also required to write the essay on a given subject.

prerequisite
No special requirements.

learning resources
Motor vehicle;

Vehicle and engine parameters data acquisition system;

Hybrid vehicle;

Electric vehicle.

number of hours: 75

active teaching (theoretical): 30
lectures: 25
elaboration and examples (revision): 5

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 12
calculation tasks: 0
seminar works: 13
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 3
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 10
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

NAVAL SYSTEMS

Buoyancy and Stability of Ship 1M

ID: MSc-0973
responsible/holder professor: Bačkalov A. Igor
teaching professor/s: Bačkalov A. Igor
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: naval systems

goals

To cover the basic knowledge of Naval Architecture connected to ship form, ship buoyancy, stability, and ship hydrostatic calculations (hydrostatic curves and stability). Buoyancy and stability is one of the basic professional courses hence taught in all the departments (faculties) with courses in naval architecture.

learning outcomes

Practical knowledge in ship line plan drawing, and in the basic hydrostatic calculations (hydrostatic curves, stability cross curves, righting arm). Ability in solving and analysis of practical engineering tasks connected to ship buoyancy and stability.

theoretical teaching

Geometry of ship hull: basic definitions and principal dimensions, coefficients of form, the lines drawing, hydrostatic curves. Initial stability of ship: righting moment, metacentric height, metacentric radius, angle of static heel, impact of wind, turning and towing, shifting loads, hanging loads and liquid cargo, dynamic stability. Longitudinal stability of ship: trim and longitudinal shifting loads. Intact stability of ship at large angles of heel: curves of centre of buoyancy, centre of flotation, and metacentre. Cross curves of stability. Righting arm and righting moment curves. Potential energy of stability. Ship with circular, wall-sided and inclined sections. Static and dynamic stability diagram. Angles of static and dynamic capsizing. Practical methods of stability calculation. Parts of ship stability. Asymmetrically loaded ship and ship with negative metacentric height. Ship stability regulations.

practical teaching

Practical problems of ship buoyancy and stability, illustrating the subjects lectured in theoretical syllabus. In addition, students work individually on three classical hydrostatic projects: ship lines drawing, ship hydrostatic curves and ship stability. The projects are completed in the Final Course Report (B.Sc. work), and defended after the sixth semester.

prerequisite

The previous study year completed. Semester 5 enrolled.

learning resources

[1] Milan Hofman: Extracts from lectures (handouts)

[2] Ribar, B., The Theory of Ship, Faculty of Mechanical Engineering, 1987 /In Serbian/

[3] Igor Bakalov: Instructions for projects in buoyancy and stability of ship

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0

calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 50
requirements to take the exam (number of points): 34

references

Biran, A., Ship Hydrostatics and Stability, Butterworth Heinemann 2003
Lewis, E.V., (editor): Principles of Naval Architecture, Part 1, SNAME 1987
K.J. Rawson & E.C. Tupper, Basic Ship Theory, Longmans 1967

Buoyancy and Stability of Ship 2

ID: MSc-0695
responsible/holder professor: Bačkalov A. Igor
teaching professor/s: Bačkalov A. Igor
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: naval systems

goals
To cover the advanced knowledge of Naval Architecture connected to ship buoyancy and stability: ship loading, flooding, damaged ship stability and grounding.

It is a continuation of the course Buoyancy and Stability of Ship 1.

learning outcomes
Ability to solve and analyze practical engineering tasks connected to ship loading/unloading, damaged ship stability and grounding. Practical knowledge of ship flooding calculations, according to international regulations.

theoretical teaching
Loading/unloading of cargo: centric loading (small and large cargo, liquid cargo), eccentric loading. Flooding: alternative methods (added weight or lost buoyancy), centric and eccentric flooding, flooding of compartments with solid and liquid cargo. Damaged ship calculations: deterministic and probabilistic calculations, curve of floodable length, regulations. Ship grounding: bottom reaction (small and large), grounded ship stability, critical reaction, docking. Methods for improving ship stability.

practical teaching
Practical problems of ship buoyancy and stability, illustrating the subjects lectured in theoretical syllabus. In addition, students have to accomplish individually the project: Flooding calculations (done in accordance to SOLAS regulations) for the ship already analyzed in projects of Buoyancy and Stability of Ship 1 (ship lines drawing, hydrostatic curves and intact stability calculations).

prerequisite
Semester 8 enrolled. Exam passed in Buoyancy and Stability of Ship 1.

learning resources
[1] Hofman, M.,: Extracts from lectures (handouts) /In Serbian/

[2] Ribar, B., The Theory of Ship, Faculty of Mechanical Engineering, 1987 /In Serbian/

[3] Bačkalov, I., Instructions for projects in buoyancy and stability of ship /In Serbian/.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0

discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 50
requirements to take the exam (number of points): 34

references
Biran, A., Ship Hydrostatics and Stability, Butterworth Heinemann 2003
Lewis, E.V., (editor): Principles of Naval Architecture, Part 1, SNAME 1987
K.J. Rawson & E.C. Tupper, Basic Ship Theory, Longmans 1967

International Maritime Regulations

ID: MSc-0494
responsible/holder professor: Bačkalov A. Igor
teaching professor/s: Bačkalov A. Igor
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: naval systems

goals
To cover the basic aspects of International Maritime Regulations, their evolution and development, and (especially) their influence on ship design. Critical analysis of the present regulations.

learning outcomes
Understanding of the basic concepts of maritime regulations, their development and their influence on ship safety, environment, and ship design.

theoretical teaching
Rules, regulations and conventions in design, construction and operation of ships. Types of regulations: prescriptive regulations, probabilistic regulations, goal-based standards. International maritime regulations: IMO Conventions; International Convention for Safety of Life at Sea (SOLAS). Tonnage Measurement – International Convention on Tonnage Measurement of Ships (Tonnage). Freeboard and load line regulations – International Convention on Load Lines (ICLL). Pollution from ships – International Convention for the Prevention of Pollution from Ships (MARPOL). International Convention for the Control and Management of Ships' Ballast Water and Sediments. Vibration and noise on ships. Regulations for construction of inland navigation vessels. European technical requirements for inland waterway vessels. Directive 2006/87/EC. ECE regulations. ADN regulations. National regulations. Impact of the regulations on ship safety, environment, and ship design. Critical analysis of the present regulations.

practical teaching
Practical examples and applications of the regulations covered by theoretical syllabus. Some detail of the regulations. Analysis of the impact of regulations on ship safety, environment, and ship design. The course is parallel to Ship Design, and the students implement the learned regulations to their individual projects.

prerequisite
Exams passed in Buoyancy and Stability of Ship 2, Ship Resistance, Ship Propulsion, Ship Structures 2.

learning resources
[1] Bačkalov, I., Extracts from lectures (handouts). /In Serbian/

[2] Maritime regulations: IMO Conventions (SOLAS, Tonnage, ICLL, MARPOL), etc.

[3] Technical requirements for inland vessels: ADN, ECE, Directive 2006/87/EC, etc.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 20
> laboratory exercises: 0
> calculation tasks: 0

seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 10
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 34

references
Kuo, Ch., Safety Management and Its Maritime Application, The Nautical Institute, 2007
Lamb, T., (editor): Ship Design and Construction, SNAME, 2003.
H. Schneekluth, V. Bertram: Ship Design for Efficiency and Economy, Butterworth-Heinemann, 1998.
Watson, D., Practical Ship Design, Elsevier, 1998.
Papanikolaou, A.D. (Editor): Risk-Based Ship Design: Methods, Tools and Applications, Springer, 2009

Seakeeping

ID: MSc-0697
responsible/holder professor: Bačkalov A. Igor
teaching professor/s: Bačkalov A. Igor
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: naval systems

goals
To cover the basic knowledge of Naval Architecture connected to ship motion in waves (seakeeping).

learning outcomes
Knowledge in solving and analysis of practical engineering tasks connected to ship motion (roll, heave, pitch) in regular and irregular waves.

theoretical teaching
Ship motion in calm water: rolling, heaving and pitching. Ship's natural periods. Added mass and damping – strip theory, the Lewis forms. Waves at sea surface: hydrodynamic theory, stochastic theory. Ship motion in regular waves: rolling, heaving and pitching. Ship motion in irregular waves: motion spectra, mean, significant and RMS values of ship motion. Displacement, velocity and acceleration of ship points. Probability of deck wetness, propeller emergence and slamming. Added resistance. Effects on passengers and crew. Dynamic loads. Seakeeping criteria. Improvement of ship seakeeping characteristics. Roll stabilization.

practical teaching
Practical problems of seakeeping, illustrating the subjects lectured in theoretical syllabus. In addition, students have to accomplish individually the project on ship rolling, heaving and pitching in irregular waves, for the ship already analyzed in projects of Buoyancy and Stability of Ship.

prerequisite
Semester 9 enrolled. Exams passed in Buoyancy and Stability of Ship 1 and Buoyancy and Stability of Ship 2.

learning resources

[1] Milan Hofman: Extracts from lectures (handouts) /In Serbian/

[2] Milan Hofman: Seakeeping /To be published in Serbian/

[3] I. Bačkalov: Instructions for seakeeping project. /In Serbian/

[4] SEAWAY: Performance analysis of ships and offshore floating structures in waves.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0

discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 50
requirements to take the exam (number of points): 34

references

Lewis, Edward V. (editor), Principles of Naval Architecture, Part 3, SNAME 1987
A.R.J.M.LLoyd: Seakeeping - Ship Behaviour in Rough Weather
Lewandowski, E., The Dynamics of Marine Craft, World Scientific 2004.

Ship design

ID: MSc-1018
responsible/holder professor: Kalajdžić D. Milan
teaching professor/s: Kalajdžić D. Milan, Momčilović V. Nikola, Motok D. Milorad, Simić P. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: naval systems

goals
To integrate the knowledge acquired from previous courses of naval architecture, and to develop knowledge and skills for the basic ship design.

learning outcomes
Ability to develop ship design, with the corresponding calculations, plans and technical documentation, for various ship types.

theoretical teaching
Basic principles of ship design: The design spiral. Weight, volume and area-based design. Weight groups. Statistic data on existing ships. Statistic data and prototype-based design. Statistics-based ship design: Formulas for main dimensions and their interrelations, ship-form coefficients, weight groups, centre of mass, power prediction. Effects of ship's dimensions and ship form on stability, resistance, strength, maneuvering and seakeeping. Ship calculations in the first approximation. Ship calculations in the second approximation. Design based on prototype: The choice of the prototype. Main dimensions, form coefficients, weight groups, centre of mass, power prediction. Lines drawing. General arrangement plan. Other technical documentation. Specifics in cargo ships design (multipurpose ships, container ships, bulk carriers, tankers), passenger ships, naval ship etc. Specifics in inland vessels design.

practical teaching
Practical problems of ship design, illustrating the subjects lectured in theoretical syllabus. In addition, students have to develop individually the project of a cargo ship (preliminary ship design of a container ship, bulk carrier, multipurpose ship or a tanker), with all the necessary calculations, plans (including the general arrangement) and the technical documentation.

prerequisite
Exams passed in Buoyancy and Stability of Ship 2, Ship

Resistance, Ship Propulsion, Ship Structures 2.

learning resources
[1] I. Bačkalov: Extracts from lectures (handouts). /In Serbian/

[2] I. Bačkalov: Instructions for project design. /In Serbian/

[3] Technical documentation of designed ships.

[4] The German Merchant Fleet, Seehafen Verlag, 2006

[5] Significant Ships, RINA Journals.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5

laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 50
requirements to take the exam (number of points): 45

references

H. Schneekluth, V. Bertram: Ship Design for Efficiency and Economy, Butterworth-Heinemann, 1998.
D.Watson: Practical Ship Design, Elsevier, 1998.
T. Lamb (editor): Ship Design and Construction, SNAME, 2003.
A. Papanikolaou: Ship Design - Methodologies of Preliminary Design, Springer, 2014

Ship Equipment M

ID: MSc-0975
responsible/holder professor: Simić P. Aleksandar
teaching professor/s: Simić P. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: naval systems

goals
The aims of the course are to familiarize students with: 1) basic ship equipment, both with the one found on each ship and with a special one found on some types of ships; 2) essential characteristics of various ship types; 3) regulations concerning ship equipment; 4) the expected development of ship types and their equipment.

learning outcomes
Having successfully mastered the teaching contents of Ship equipment, the student should demonstrate fundamental knowledge about:

1) ship equipment;

2) various types of ships and their essential characteristics;

3) the expected development of ship equipment and ship types etc.

theoretical teaching
In brief, the course comprises the following teaching units:

1) Deck equipment (anchoring, mooring and steering device).

2) Cargo access equipment (for vertical and horizontal cargo handling), ship cranes. 3) Safety equipment (rescue, navigational).

The Ship equipment course gains in importance concerning the fact that ships differ in the first place in the installed equipment. The cost of ship is considerably affected

by the installed equipment. Ship equipment, on the other hand, is not manufactured in the shipyards but is manly purchased from specialized manufacturers. That is, to some extent, the reason why the content of the course is mainly encyclopedic in its character.

practical teaching
The student is in the focus of practical teaching. Attention is directed to the application of knowledge, previously attained by theoretical teaching, and needed for common engineering practice. Emphasis is placed on classification societies' rules related to ship equipment. World leading ship equipment manufacturers' brochures and leaflets provide a source for students to get acquainted with technical characteristics and specificities of equipment installing, depending on the type of ship.

prerequisite
There are no prerequisites

learning resources
Lectures are available in electronic form

Various classification societies' rules

Brochures of various equipment manufacturers

Internet resources

number of hours: 30

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 20

references
D. J. House: Seamanship Techniques, Shipboard and Marine Operations, Elsevier, Oxford, 2004.
Bosnic, Vukicevic: Oprema broda, Fakultet strojastva I brodogradnje, Zagreb, 1983.
Camac, brod, brodogradnja, Tehnicka enciklopedija, Jugoslavenski leksikografski zavod, Zagreb.
L. Buxton, R. Daggitt, J. King: Cargo Access Equipment for Merchant Ships, E&F. N. Spon Ltd. London 1978.

Ship manoeuvring

ID: MSc-0958
responsible/holder professor: Simić P. Aleksandar
teaching professor/s: Simić P. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: naval systems

goals
The aims of the course are to make the student familiar with:

1) Essential features of ship maneuverability so that the navigation is as safe as possible;

2) Standard tests and criteria for ship maneuverability estimation;

3) ITTC and IMO regulations;

4) Ship design in respect to its maneuverability (course keeping, turn ability, response to rudder deflection etc.).

learning outcomes
The student should know:

1) Basic features of ship maneuverability and criteria for its estimation;

2) To interpret regulations for maneuverability and to conduct maneuverability tests; 3) To know which measures should be undertaken in ship design to provide satisfactory ship maneuverability.

theoretical teaching
Theoretical teaching focuses on familiarizing the student with general principles of maneuverability, necessary mathematical formulations and stability criteria. Introduction of standard maneuverability tests (spiral and reverse spiral test, zig-zag maneuver, turning path, pullout test etc.). Captive and free running model tests (PMM, rotating arm technique etc.) are explained. Hydrodynamics of control surfaces (rudders) follows.

practical teaching
Practical teaching focuses on the application of knowledge to common engineering practice. Practical explanations are given for performing standard maneuverability tests. Students are familiarized with active (bow thrusters, azimuth thrusters, etc.) and passive control devices (various types of rudders). Recommendations are given for ship design and meeting the criteria defined by IMO regulations.

prerequisite
There are no prerequisites.

learning resources
Lectures are available in electronic form

A detailed prominent example of the manoeuvring tests

Brochures of various equipment manufacturers

Internet resources

number of hours: 30

> **active teaching (theoretical):** 12
> lectures: 8
> elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 1
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 25

references
E. Lewis, (editor): Principles of Naval Architecture (Chapter IX – Controllability), SNAME, Jersey City, 1988.
J. Brix: Maneuvering Technical Manual, Seehafen Verlag, Hamburg, 1993.
A.F. Molland, S.R. Turnock: Marine Rudders and Control Surfaces, Butterworth – Heinemann, 2007

Ship propulsion

ID: MSc-0956
responsible/holder professor: Simić P. Aleksandar
teaching professor/s: Simić P. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: naval systems

goals
The aims of the course are to familiarize the student with various types of ship propulsors (specifics, advantages and drawbacks, selection of the best propulsor etc.). Practical training should enable the student to select/design the most adequate propulsor by applying common engineering methods, to use computer for those activities, to know how to determine necessary engine power.

learning outcomes
The student should be familiar with various types of ship propulsors and propellers in particular, their advantages and drawbacks, the concept of ship propeller design by applying common engineering methods, how to determine the needed ship engine power output.

theoretical teaching
Theoretical teaching involves familiarity with interaction between the hull and the propeller (propulsive coefficients), joint operation of the ship propeller and the engine, types of propellers and, lastly, the selection/design of propellers by using common engineering methods. Explanations are given of basic elements needed for the sea trials. The model tests and interpretation of their results are examined too.

Finally, the student is familiarized with various types of propulsors based, more or less, on the screw propeller (for example, propeller in the nozzle) as well as with those that are considerably different and are often installed in unconventional ship types or boats (for example, water-jet propulsor). Also, transmission of power from the engine to the propulsor, which influences propulsor in great extent, is mentioned.

practical teaching
In addition to common calculation examples that follow teaching units presented theoretically, the focus is on the student's independent design of project (which is actually a continuation of the project included in the Ship resistance course). The project, in brief, consists of performing calculations by applying common engineering methods (some with the use of the computer) to select/design the optimal propeller and then choose an adequate ship engine. Besides, the student should produce a technical drawing of the propeller.

prerequisite
Exam passed in Ship resistance.

learning resources
Lectures are available in electronic form

A detailed prominent example of the project

Internet resources

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 60
requirements to take the exam (number of points): 20

references
E. Lewis,(editor): Principles of Naval Architecture (Chapter VI – Propulsion), SNAME, Jersey City, 1988.
SNAME's Principles of Naval Architecture Series: Propulsion, Justin E. Kerwin and Jacques B. Hadler, 2010.
Molland, A.F., Turnock, S.R. and Hudson, D.A. „Ship Resistance and Propulsion: Practical Estimation of Ship Propulsive Power“, Cambridge University Press, Cambridge, 2011.
John Carlton, Marine Propellers and Propulsion, Butterworth-Heinemann, 2012.
Sv. AA. Harvald: Resistance and Propulsion of Ships, John Willey & Sons, 1983.

Ship resistance

ID: MSc-0955
responsible/holder professor: Simić P. Aleksandar
teaching professor/s: Simić P. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: naval systems

goals
The aims of the course are to familiarize students with: 1) fundamentals of ship hydrodynamics; how elementary ship form parameters affect ship resistance; 2) how to determine resistance for conventional ships types by applying standard engineering methods and by analyzing the results of model tests; 3) unconventional types/forms of ships from the aspect of ship resistance (shallow draught river vessels, planing and semi-displacement high speed craft, etc.).

learning outcomes
1) Basic knowledge about ship hydrodynamics needed for the design of conventional types of ships.

2)Ability to do calculations of ship resistance at the common engineering practice level.

3) Knowledge about basics of model tests and extrapolation of results from model to ship scale.

4) Basic knowledge about unconventional ship types and their forms.

theoretical teaching
To determine the ship's main engine power, ship resistance must be determined first. It can be obtained by model tests or by other evaluation methods. Teaching is primarily oriented to practical application of ship hydrodynamics in common engineering practice. Attention is particularly focused on model tests that are still the most reliable tool as well as on the extrapolation of results from a model to a ship. Theoretical teaching is realized through the following teaching units: a) calculations of ship resistance components, resistance evaluation according to ITTC recommendations/method, b) effects of shallow and restricted water, c) model tests, model-ship correlation, standard methodical and statistical series, d) recommendations for design of ship forms, and e) high-speed (unconventional) craft.

practical teaching
The student should evaluate resistance for a usual sea-going ship (form) he/she was acquainted within the subject Buoyancy and stability of ship 1; obtained results will be used in the project that should be done within Ship propulsion course. Thus, the student is enabled to perceive the ship as a whole, and resistance itself as a part of applied ship hydrodynamics that is unavoidable in the ship design process. Within the framework of practical teaching the student is trained to do calculations using a computer i.e. to develop and apply a mathematical model for resistance evaluation by himself. Moreover, some teaching units presented by theoretical teaching involve calculation examples too.

prerequisite
Exams passed in Fluid mechanics and Buoyancy and stability of ship 1

learning resources
Lectures are available in electronic form

A detailed prominent example of the project

Internet resources

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 0
calculation tasks: 9
seminar works: 0
project design: 8
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 60
requirements to take the exam (number of points): 20

references
E. Lewis (editor): Principles of Naval Architecture (Chapter V – Resistance), SNAME, Jersey City, 1988.
Molland, A.F., Turnock, S.R. and Hudson, D.A. „Ship Resistance and Propulsion: Practical Estimation of Ship Propulsive Power", Cambridge University Press, Cambridge, 2011.
M. Hofman and D. Radojcic, Resistance and propulsion of High Speed Crafts in Shallow Water, MF Belgrade, (in serbian)
A. J. W. Lap, J. D. Van Mannen: Fundamentals of Ship Resistance and Propulsion (Part A – Resistance), NSMB Publication 129A.
Sv. AA. Harvald: Resistance and Propulsion of Ships, John Willey & Sons, 1983.

Ship strength 1

ID: MSc-1015
responsible/holder professor: Momčilović V. Nikola
teaching professor/s: Momčilović V. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: naval systems

goals
The aims are to explain: basic modes of ship structure failure and limit state assessment of ship structure, general simplification of the hull mathematical model and the concept of strength calculations by using analytical and numerical methods.

learning outcomes
1. A thorough knowledge about the concept of ship strength calculations in contemporary shipbuilding practice. 2. Qualification for practical application of analytical methods of theory of elasticity in direct calculations of ship structures and analysis and development of classification societies' rules.

theoretical teaching
The student is familiarized with various types of ship structure failure and limit states. Basic hull loadings are considered and their classification into static, quasi-static and dynamic ones is explained. Basic concept of the analysis of primary, secondary and tertiary structure response is explained as well as conditional division of those calculations into longitudinal, transverse and local strength. Studies comprise, first of all, analytical and some numerical methods for calculations of beams, grids, unstiffened and stiffened plates of ship structure. Explanations are given of a general concept of the corresponding hull mathematical model, simplifications to be applied for the sake of analytical methods use, limitations of such approach to analysis, and alternative numerical methods that help to overcome those limitations.

practical teaching
Calculation tasks are used to develop student ability to independently do strength calculations of beams and plane grids of ship structure, and analysis of bending and stability of unstiffened plates and stiffened panels of ship structure. In modern engineering practice those skills are needed in both direct calculations of the hull strength and for understanding and development prescriptive formulas in classification societies' rules.

prerequisite
Defined by the Study Program Curriculum.

learning resources
1. Examples of solved calculation tasks /In Serbian/. 2. Shipbuilding rules by various classification societies /In Serbian and English/.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 17
laboratory exercises: 0
calculation tasks: 10
seminar works: 0

project design: 0
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 50
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 10

references
M. Motok: Ship Strength /In Serbian/, MF, Beograd, 2005.
J. Khlitchiev: Chapters on Calculations of Ship Structures /In Serbian/, MF, Beograd, 1972.
J. Ursic: Ship Strength I, II, III /In Serbian/, FSB, Zagreb, 1972.1991.1992.
O. F. Hughes: Ship Structural Design, John Wiley & Sons, New York,1983.
***: Ship Design and Construction, Vol I, SNAME, 2003.

Ship strength 2

ID: MSc-1017
responsible/holder professor: Momčilović V. Nikola
teaching professor/s: Momčilović V. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: naval systems

goals
The aims of the course are to explain the basic principles of numerical methods for structural analysis, theoretical and practical fundamentals of finite element method and to provide a thorough explanation of finite element method application in ship structure design.

learning outcomes
1.A thorough knowledge about the concept of structural analysis by applying finite element method as one of the most significant methods for structural analysis in contemporary engineering practice. 2. Qualification for practical application of a commercial FEM program package in direct computations of ship structure.

theoretical teaching
Teaching focuses on the finite element method as one of the most significant numerical methods for structural analysis in contemporary engineering practice. The idea is to organize the course as a first encounter with finite element method for those students for whom it is not a major subject of study but only one of the tools they have to master to manipulate. That is why a portion of approach is simplified, where it is not insisted upon all details of mathematical derivations but upon aspects essential to proper practical FEM analysis by applying commercial program packages.

practical teaching
The student is trained to independently do computations for typical models of ship structure by using a computer and commercial program packages. It is started from less complex beam models – ship's cross-sectional frames and plane hull structure grids, and through models of stiffened and unstiffened panels, involving thin plate finite elements, it is gradually arrived at complex web frame and three hold models.

prerequisite
Exam passed in Ship Strength 1.

learning resources
1. Commercial FEM computer programs. 2. Instruction manual for commercial FEM programs use. /In English/.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 10
> laboratory exercises: 18
> calculation tasks: 0
> seminar works: 0
> project design: 0
> consultations: 2

discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 50
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 40

references
M. Motok: :Ship Strength /In Serbian/, MF, Beograd 1995.
M. Kalajdzic: Finite Element Method /In Serbian/, IAMA, Beograd, 1978.
C.T.F Ross: Advanced Applied Finite Element Methods, Harwood Publishing, Chichester,1998.
O.F. Hughes: Ship Structural Design, John Wiley & Sons, New York,1983.
***: Ship Design and Construction, Vol I, SNAME, 2003.

Ship Structures 1M

ID: MSc-0974
responsible/holder professor: Motok D. Milorad
teaching professor/s: Momčilović V. Nikola, Motok D. Milorad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: naval systems

goals
The aims of the course are to explain the requirements that hull structure has to meet, and as a result, to gain essential understanding of its general conception, to familiarize the student with the hull structural members to the design details level, to develop student skills to practically apply standard engineering methods used for steel hull structure scantling definition.

learning outcomes
A thorough knowledge of general concept and structural members of the welded steel ship hull. The student should be able to practically apply rules for building ships by various classification societies.

theoretical teaching
Theoretical teaching is partially encyclopedic in character. The student becomes familiar with the hull basic structural members (terminology presented in both Serbian and English), appearance, basic functions, and loads they undergo during exploitation, method of fabrication, and their versatility and design, depending on ship type and size, applied framing system and the like. On the other hand, both basic principles and methodology for hull scantling definition are considered in parallel, first of all, from the aspect of strength. The history and today's role of classification societies is considered, their rules and basic aspects of some direct calculations are explained.

practical teaching
A detailed prominent example is used to explain the procedure of hull structure scantling definition according to Lloyd's Register Rules. Within the framework of independent project design the student is dimensioning the following structural members of midship section using "his own" concrete example of the ship: plating and the stiffening system of bottom and inner bottom; plating and the stiffening system of ship sides; plating and the stiffening system of weather and cargo deck; plating and the stiffening system of water-tight bulkheads; pillars in 'tween deck and hold; fore peak structure; after peak structure.

prerequisite
Defined by the Study Program Curriculum

learning resources
[1]Lectures are available in electronic form /In Serbian/

[2] A thorough prominent example of the project

[3] Various classification societies' rules

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 12
> laboratory exercises: 0

calculation tasks: 0
seminar works: 0
project design: 14
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 35

references
M. Grubisic: Ship structures /In Serbian/, FSB, Zagreb, 1980.
D.J. Eyres: Ship Construction, London, 1972.
***: Ship Design and Construction, SNAME, 2003.
N. Barabanov: Structural Design of Seagoing Ships, Peace Publishers, Moscow, 1980.

Ship Structures 2

ID: MSc-0197
responsible/holder professor: Motok D. Milorad
teaching professor/s: Momčilović V. Nikola, Motok D. Milorad
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: naval systems

goals
A thorough explanation of the hull girder longitudinal strength calculation. An explanation of specific requirements that have to be met by the hull of the three most prominent ship types: a container ship, a bulk carrier and a tanker.

learning outcomes
The student should be able to practically perform hull girder longitudinal strength calculation according to classification societies' rules. A thorough knowledge should be acquired of specifics, general conception and the hull structural members of tankers, bulkers and container ships.

theoretical teaching
The first part of the course considers basic principles and methodology of longitudinal strength calculation: determination of hull girder loading on the basis of specific buoyancy and specific weight per ship unit length; determination of geometrical characteristics of hull girder crosssection; computations of wave induced transverse force and bending moment using classification societies' empirical formulas; analysis of the overall stress state. The second part of the course comprises basic structural members and specifics of the hull structure in a tanker, a bulk carrier and a container ship – their names, appearance, basic functions, conditions and loadings they undergo during exploitation, methods of construction.

practical teaching
A detailed prominent example is used to explain the procedure for hull girder longitudinal strength calculation according to classification societies' rules. Within the framework of independent design project of "his own ship" the student determines: equivalent hull girder loading on the basis of specific buoyancy curve and specific weight curve per ship unit length; geometrical characteristics of hull girder cross-section; wave induced transverse force and bending moment using classification societies empirical formulas and conducts final analysis of the overall stress state.

prerequisite
Exam passed in Ship Structures 1.

learning resources
[1] Lectures are available in electronic form /In Serbian/

[2] A detailed prominent example of the project

[3] Various classification societies' rules

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 9
> laboratory exercises: 0

calculation tasks: 0
seminar works: 0
project design: 17
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 0
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 35

references

M. Grubisic: Ship strucrures /In Serbian/, FSB, Zagreb, 1980.
***: Ship Design and Construction, SNAME, 2003.
D.J. Eyres: Ship Construction, London,1972.
N. Barabanov: Structural Design of Seagoing Ships, Peace Publishers, Moscow, 1980.

Ship systems M

ID: MSc-1016
responsible/holder professor: Kalajdžić D. Milan
teaching professor/s: Kalajdžić D. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written+oral
parent department: naval systems

goals
To cover the basic knowledge of Marine Engineering connected to ship piping and pumping systems.

learning outcomes
Ability in basic design, calculations and analysis of ship piping and pumping systems: bilge, ballast,emergency, heeling, sanitary, tanker, firefighting systems, etc.

theoretical teaching
Ship piping systems: pressure diagram, piping characteristics, characteristics of marine pumps, joint operation of pumps and a piping, suction head problems. Piping armature. Types of marine pumps. Individual ship systems: Bilge system, emergency system, rescue system; Ballast system; Heeling and trim system; Sanitary systems: system of fresh and sea water, system of waste water. Drainage system. Tanker systems: cargo system, stripping system, tank ventilation, tank cleaning, cargo circulation, cargo heating system. MARPOL Regulations. Firefighting systems: fire detection, fire-fighting systems (water, inert gases, foam, halons).

practical teaching
Principle design and calculations of various ship piping and pumping systems. Practical examples of ship systems, illustrating the subjects lectured in theoretical syllabus.

prerequisite
Exams passed in Fluid mechanics B or M.

learning resources
[1] Extracts from lectures (handouts) /In Serbian/.

[2] Instructions for making tasks from ship systems /In Serbian/.

[3] Technical documentation: Examples of ship systems. Catalogues of marine pumps and armature.

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 18
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 10

references
R.L. Harrington: Marine Engineering, SNAME 1992
A. Rowen et al: Introduction to Practical Marine Engineering, SNAME 2005

Skill Praxis M - BRO

ID: MSc-1220
responsible/holder professor: Kalajdžić D. Milan
teaching professor/s: Kalajdžić D. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: naval systems

goals
The student gains practical experience in the occupational environment where he will pursue his future career. He identifies essential functions of the business system in the domain of design, development and manufacturing as well as the role and tasks of a naval architect within such business system.

learning outcomes
The student should gain practical experience in the way of organizing and functioning of the environment where he will apply the acquired expert knowledge, identify models of communication with his colleagues and business information flows, identify fundamental processes in design, manufacturing, maintenance within the context of his future competence, establish personal contacts and acquaintances he will make use of during his schooling, or when applying for job in the future.

theoretical teaching
-

practical teaching
Practical teaching involves work in organizations where various activities are performed that have to do with naval architecture. The student chooses thematic unit and manufacturing company or research institution after consulting the Professor. In general, the student is allowed to conduct skill praxis in: shipyards, design and consulting agencies, companies dealing with ship and machinery maintenance, or one of the laboratories at the Faculty of Mechanical Engineering. Skill praxis can be done abroad as well. The student is obliged to keep a diary of skill praxis, where he will describe jobs he is doing, record his conclusions and remarks. After he completes the skill praxis, the student makes a report and provides explanations to the Professor. The report is handed over in the form of a seminar work.

prerequisite
It is only recommended to students MODULE OF NAVAL ARCHITECTURE

learning resources
-

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 85
> auditory exercises: 0
> laboratory exercises: 80
> calculation tasks: 0
> seminar works: 5
> project design: 0
> consultations: 0
> discussion and workshop: 0
> research: 0

knowledge checks: 5
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 60
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 10

references

Software application in Ship design

ID: MSc-1019
responsible/holder professor: Kalajdžić D. Milan
teaching professor/s: Kalajdžić D. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: naval systems

goals
To cover the application of computer program packages for ship design and basic ship calculations.

learning outcomes
Practical knowledge in applying computer programs for developing ship form, hydrostatic computations, power prediction, hull structure scantling, seakeeping and ship design.

theoretical teaching
Concepts and basic aspects of the application of computer programs and commercial software packages for shipbuilding. Some basic software packages connected to ship geometry, lines drawing, hydrostatic computations, hull construction, power prediction, ship manoeuvring and seakeeping are explained and demonstrated.

practical teaching
Students are trained to work with available software packages, in order to solve practical engineering problems of ship geometry, lines drawing, hydrostatic computations, construction, power prediction, manoeuvring and seakeeping. The course is parallel to the Ship Design, and the students use the software for developing their individual ship design project.

prerequisite
Exams passed in Buoyancy and Stability of Ship 2, Ship Resistance, Ship Propulsion, Ship Structures 2.

learning resources
[1] Extracts from lectures (handouts) /In Serbian/

[2] Support for software packages: AutoCAD, DelftSHIP, AutoShip (ModelMaker, AutoHydro), HydroComp, GL Rules.

[3] Internet resources

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 0
laboratory exercises: 18
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 60
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
DELFTshipTM user manual
AutoCAD user manual

PHYSICS AND ELECTRICAL ENGINEERING

Biomedical instrumentation and equipment

Biomedical instrumentation and equipment

ID: MSc-1323
responsible/holder professor: Stojić M. Tomislav
teaching professor/s: Lukić M. Petar, Stojić M. Tomislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: physics and electrical engineering

goals
Introducing to standard measuring and diagnostically medical methods and implementation of electron devices in medicine. The focus is on the principles and operation methods of the biomedical equipment with brief description of device construction and function of some devices. The subject educates engineers to work together with other experts to improve existing and develop new biomedical equipment.

learning outcomes
By attending the course, students will be educated to understand and analyze problems concerned with operation and usage of biomedical instrumentation and equipment. This course educate students to connect basic principals of electronics, physics and medicine and to practically implement them into modern medical equipment.

theoretical teaching
Principles of medical measurements and instrumentation. Sensors for biomedical measurements. Electric and magnetic stimulators. Ultrasound in medicine - overview of the diagnostically methods: tomography, cardiosonography, measurement of blood flow (Doppler). Methods based on medical imaging - Rontgen, computer tomography, Anger camera, nuclear magnetic resonance, positron emitting tomography, thermograph. Medical image processing. Medical image generation: digital and digitalized image. Basic methods for image processing.

practical teaching
Basic principles of medical measurements and instrumentation. Overview of the sensors and their characteristics that are used for biomedical measurements. Basic modules of the electric muscle stimulator - presentation. Ultrasound in medicine - overview of the diagnostically methods: tomography, cardiosonography, measurement of blood flow (Doppler). Generating of the medical image - examples. Digitalization of analogous image. Medical image processing. Basic methods for image processing. Basic methods for digital medical image improving. Morphology methods for image processing. Practical examples from clinical practice.

prerequisite
mandatory Electrical engineering and preferably Electronics

learning resources
[1] P. Lukić, Analog electronics fundamentals, Faculty of Mechanical Engineering, University of Belgrade, 2015, ISBN 978-86-7083-855-0, /In Serbian/
[2] Joseph D. Bronzino (editor): The Biomedical Engineering - Handbook, CRC Press, IEEE Press, USA, 1995.
[3] D. M. Škatarić, N. V. Ratković, T. M. Stojić, P. M. Lukić: Solved Numerical Problems in Electro technique, Faculty of Mechanical Engineering, Belgrade, 2000.
[4] D. B. Kandić: Electro technique, Faculty of Mechanical Engineering, Belgrade,2002.
[5] Printed excerpts from lectures (handouts) /In Serbian/

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 25
laboratory exercises: 0
calculation tasks: 0
seminar works: 3
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 0
final exam: 35
requirements to take the exam (number of points): 35

references
P. Lukić, Analog electronics fundamentals, Faculty of Mechanical Engineering, University of Belgrade, 2015, ISBN 978-86-7083-855-0, /In Serbian/
Mirjana Popović, Milica Janković, Dejan Popović: Biomedical measurements and instrumentation, Akademska misao, Beograd, 2009., ISBN: 978-86-7466-371-4, /In Serbian/

PROCESS AND ENVIRONMENTAL PROTECTION ENGINEERING

Air Pollution Control

ID: MSc-0124
responsible/holder professor: Radić B. Dejan
teaching professor/s: Obradović O. Marko, Radić B. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written+oral
parent department: process and environmental protection engineering

goals
The goal of course is a review of basic design devices used in facilities whose purpose is the air pollution control. This is achieved through a review of the basic construction of apparatus for the purification of gases and review of methofdology for calculations commonly used types of these devices. In this way the student masters the skills of designing these facilities and individual devices.

learning outcomes
Upon completion of the course is expected that the candidate has mastered the skills related to analysis and evaluation of application of air pollution control devices for a particular purpose. The knowledge that the student acquire the specific technical solutions, selection of treatment methods and equipment enabling the understanding of basic principles essential for the design of air pollution control installations and calculation of particular devices.

theoretical teaching
Apparatus for particulate emission reduction – Inertial and gravitational devices, centrifugal separators, electrostatic precipitators, fabric filters.

Apparatus for wet particulate and gas emission reduction – Spray towers, scrubbers (spray, cyclone, baffle, impigment etc), venturi scrubber.

Dry, wet and semidry gas emission control – wet scrubbers, absorbers, adsorbers, packed bed absorbers, condensers.

SOx, NOx and VOC control.

practical teaching
Design of settling chambers.

Design of centrifugal separators.

Design of fabric filters.

Design of wet scrubbers.

Desing of Venturi scrubbers.

Material balances of air pollution control devices.

Design od apsorbers for gas cleaning.

NOx removal devices.

VOC removal devices.

Laboratory – measurement of particulate and gas emission.

prerequisite
Defined by curriculum of study program/module.

learning resources

1. Kuburović, M., Jovović A., Stanojević, M., Karan, M., Radić, D., Petrov, A.: Environmental protection (Chapter 15), Termotehničar, Interklima – V. Banja, SMEITS–Belgrade, 2004., KPN

2. Vuković, D, Bogner, M.: Cleaning technique, SMEITS, Belgrade, 1996, KDA

3. Experimental installation for air emission measurements, Laboratory for process engineering (room 6) EOP-LPI

4. Devices and apparatus for for air emission measurements, Laboratory for process engineering (room 6) EOP-LPI

number of hours: 30

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 11
laboratory exercises: 1
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 70
requirements to take the exam (number of points): 20

references

S.Calvert, H.M.Englund, Handbook of Air POLUUTION Technology, John Wiley & Sons, 1984.
C.C.Lee, S. D. Lin, Handbook of Environmental Engineering Calculations, Second Editions, Mc Graw Hill, 2007.

Biotechnology

ID: MSc-1264
responsible/holder professor: Karličić V. Nikola
teaching professor/s: Karličić V. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: process and environmental protection engineering

goals
The purpose of subject is for students to get knowledge about basic processes and equipment, which is used in biotechnology. Through the semester students' projects, students get creative and specific practical skills for construction of process equipment. The laboratory exercises have the aim to give appropriate knowledge to students about examination of process equipment during the production as well as the exploitation process.

learning outcomes
After successful course attending students get ability for: analysis, synthesis and predicting solutions and consequences; developing of critic and self critic thinking and approach; practical knowledge implementation; professional ethic; connecting knowledge from different subjects and their implementation; developing skills and abilities for knowledge implementation in adequate area.

theoretical teaching
1. Basics of biotechnology (definitions, products and raw materials), 2. Basics processes and designing of biotechnology, 3. Bioreactors (continuous, batch), 4. Processes and equipment of biotechnology, 5. Processes, equipment and materials for sterilization processes (thermal and mechanical processes), 6. Mathematical modeling of fermentation processes (Monod equation, stoichiometry of bioprocess), 7. Biotechnological processes for waste materials treatment (waste water: bioaeration tanks, biofilters, biodiscs; solid waste: composting, landfills), 8. Treatment of waste materials in anaerobic processes (digesters, landfills), 9. Biotechnological processes for gas cleaning.

practical teaching
1. Basic products of biotechnology, 2. Raw materials in biotechnological processes, 3.

Selection of bioreactors construction, 4. Construction characteristics of bioreactors, 5. Laboratory exercise: Determination of aerator characteristics in bioreactors with aeration agitation, 6. Determination of thermal sterilization process parameters, 7. Equipment for sterilization processes, 8. Biological treatment methods of domestic, industrial and agricultural waste, 9. Biotechnological equipment for waste water treatment, 10. Design of bioreactors – anaerobic digesters.

prerequisite
Compulsory course. There is no specific requirement for course attending.

learning resources
1. Kuburović, M., Stanojević, M.: Biotechnology – processes and equipment, Edition "Process technique", SMEITS, Belgrade, 1997., KPN

2. Laboratory facility for determination of aerator characteristics in bubble aeration

bioreactors, Laboratory of process technique (room 6), LPT

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 19
laboratory exercises: 2
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 9
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 70
requirements to take the exam (number of points): 16

references
Kuburović, M., Stanojević, M.: Biotechnology – processes and equipment, Edition "Process technique", SMEITS, Belgrade, 1997., KPN
Bogner, M. at all.: Handbook of thermal technique, Interklima grafika, Vrnjačka Banja, 2003
Rehm, H. J., Reed, G., Brauer, H.: Biotechnology, Vol. 2, Fundamentals of Biochemical Engineering, VCH Verlagsgesellschaft, mbH, Weingeim, 1985.
Jackson, A. T.: Proces Engineering in Biotechnology, Open University Press, Buckingham, 1990.
Veljković, V.: Basics of biochemical engineering, Faculty of technology, Leskovac, 1994.

Chemical and Biochemical Operations and Reactors

ID: MSc-0301
responsible/holder professor: Radić B. Dejan
teaching professor/s: Obradović O. Marko, Radić B. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: process and environmental protection engineering

goals

The purpose of subject is for students to get knowledge about theories of kinetic and dynamic of physical-chemical transformations in various technological processes. Influence of process parameters to gaining conditions for physical and chemical equilibrium is separately considered. Getting knowledge about basic models of chemical reactors, types of chemical reactions, rules used for qualitative and quantitative description of complex physical-chemical phenomenon and mass and heat balance equation, gives students basic for independent projecting of technologies and systems of process industry.

learning outcomes

Successful completion of the study program the student acquires the knowledge necessary to understand the kinetics of chemical reactions and to master the methodology of calculation of chemical processes and reactors. Introduction to basic models of chemical reactors and material equations and thermal balance should allow students to independently analyze the real process, that the application of engineering and scientific methods to be able to design processes and systems.

theoretical teaching

Classification of chemical reactions. Mechanism of complex chemical reactions. Chemical equilibrium. Chemical equilibrium constant. Influence of process parameters on chemical equilibrium and chemical reaction. Material and heat balance of chemical reactions. Heats and free energies of formation. Enthalpy, entropy and free energy. Half life. Degree of conversion.

Kinetic equation of chemical reaction. Rate of chemical reaction. Order of chemical reaction. Basic principles of design of heterogeneous systems. Rate constants of complex reactions. Classification and models of chemical reactors. Ideal chemical reactors. Material and heat balance of reactor. Batch reactors. Continuous stirred-tank reactors. Plug flow reactors. Cascade of continuous ideal reactors. Analysis of rate equations. Analysis and modeling of chemical reactors. Design of chemical reactors and processes.

practical teaching

Calculations of multicomponent and multiphase systems. Determination of chemical equilibrium constant.
Basic principles of thermodynamic for chemical reactions. Heat effect of chemical reactions.
Exothermic and endothermic chemical reactions.
Analysis of complex chemical reactions.
Calculation of the rate of chemical reaction. Order of chemical reactions.
Design of chemical reactors and processes – material and heat balances.
Calculations of ideal reactors (batch reactors, continuous stirred-tank reactors, plug flow reactors, cascade of continuous ideal reactors).
Comparation and selection of type of reactor.
Chemical reactor plant. Process optimization.

prerequisite

Defined by curriculum of study program/module

learning resources

1. Levenspeil, O.: Chemical reaction engineering, serbian translation, Belgrade, 1991.

2. Вороњец, Д., Кубуровић, М.: Thermodynamics of multicomponent systems and chemical thermodynamics, Faculty of mechanical engineering, Belgrade, 1991.

3. Perry's Chemical Engineering Handbook, Mc-Graw Hill, 1999.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 2
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 7
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 28

references

Смирнов, Н.Н., Волжинскии, А.И., Химические реактори в примерах и задачах, Химија, Ленинград, 1986.
Coulson, J. M., Richardson, J. F.: Chemical Engineering, Vol. 3: Chemical Reactor Design, Biochemical Reaction Engineering including Computational Techniques and Control, Pergamon Press, Oxford, 1982.
Smith, J.M., Van Ness, H.C., Addott, M.M.: Chemical Engineering Thermodinamics, McGraw International Edition, ISBN: 0-07-240296-2, 2001.
Walas S. M.: Chemical Process Equipment, Selection and Design, Butterworth-Heinemann, 1990.

Design, construction and operation of processing systems

ID: MSc-0363
responsible/holder professor: Petrović L. Aleksandar
teaching professor/s: Petrović Lj. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: process and environmental protection engineering

goals
Objective of the course is to introduce students to different stages of construction, from technical documentation preparation and obtaining the necessary approvals to construction and exploitation. Students learn about with the contents of the project. In the second part of the course acquire basic knowledge related to activities that follow design of processing industry facilities (power supply, operating fluids, transport, water flow etc.). Part of the course deals with the economic evaluation of investments.

learning outcomes
Main outcome of the course is to teach students to independently run object construction. This includes project documentation preparation and object construction. After successful completion of the study program, student is capable to foresee the extent of necessary design work in processing industry, as well as to plan necessary installation for production plants.

theoretical teaching
Legal framework for building facilities. Planning and Construction Law. Aim of design. Building capital investment facilities. Types of mechanical engineering projects. Content of a mechanical engineering project. Workplace safety. Fire protection. Environment protection. Assessment of impact on environment. Design of technology supported production line. Drawing schemes of technology systems and production systems. Marking of apparatus, valves, fittings and equipment for measuring and regulation on technological schemes. Technology warehouses and transport systems. Plants for energy supply. Basic forms of energy: heat (thermal), electrical and mechanical (potential and kinetic energy). Power systems. Operating fluids (water, air, technical gases).Distribution of water vapor. Compressed air and technical gases. Heating, air-conditioning and ventilation. Maintenance of production and technology systems. Assessment of services in building capital investment facilities. Investment costs. Feasibility study. Exploitation costs.

practical teaching
Introduction to the investment technical documentation. Introduction to the format of mechanical engineering projects. Examples of calculation of technology supported production lines. Examples of drawing technology systems schemes. Designing warehouses and transport systems. Power supply systems. Compressed air supply. Design of facilities for energy supply. Distribution of operative fluids. Budget and validation of investment. Exploitation and investment costs of facility operation. Independent realization of the main machine engineering project according to the predefined project task.

prerequisite
Defined with curriculum of study program / module

learning resources
Bogner M.: Design of thermotechnical and process systems, Third revised edition, Belgrade, 2007., KDA.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 25
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 3
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 30

references
Handouts
Perry's Chemical Engineering Handbook, Mc-Graw Hill, 1999.
Bogner M.: Design of thermotechnical and process systems, Third revised edition, Belgrade, 2007., KDA.

Heat transfer operations and equipment

ID: MSc-1057
responsible/holder professor: Genić B. Srbislav
teaching professor/s: Genić B. Srbislav, Ivošević M. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: process and environmental protection engineering

goals
Analysis of the mass transfer operations and apparatuses and assessment of their role in modern industry. Understanding the most commonly used types of mass transfer apparatuses - their design and calculation procedures.

learning outcomes
The mastery of calculation procedures needed to analyze the mass transfer operations - the material balance, determination of the operational line and driving force. The mastery of calculation procedures for sizing of the most commonly used mass transfer apparatuses.

theoretical teaching
Classification of mass transfer operations and basics principles of mass-transfer operations
General calculation procedure for mass transfer operations. Operation and equilibrium line, mass transfer driving force, number of transfer units, theoretical stage.
Mass transfer operations: distillation (continuous evaporation, single stage distillation, continuous condensation, distillation with deflegmation, differential distillation, fractional distillation, differential condensation), rectification, absorption, extraction, leaching, adsorption, drying.
Mass transfer apparatuses for gas-liquid systems, liquid-liquid and solid phase - fluid. Trayed and packed columns, drying chambers, etc.
Membrane mass transfer operations and and apparatuses.
Development trends in the field of mass transfer operations and apparatuses.

practical teaching
Examples of mass transfer operations. Mass and heat balancing. Determination of the operating line, driving force, the number of transfer units, the number of theoretical stages.

Examples of sizing of most commonly used mass transfer apparatuses: distillation column (with packing and with trays), extraction columns (with packing and with trays), adsorber (with a fixed layer of adsorbent), dryers (continuous and periodical).

Design procedures for membrane mass transfer operations and and apparatuses.

prerequisite
Defined in curriculum of the study program of the module.

learning resources
Jaćimović B., Genić S., Heat Transfer Operations And Equaipment, Part 1: Recuperative Heat Exchangers, Mašinski Fakultet Beograd, 2016.

Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.

Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.

number of hours: 75

active teaching (theoretical): 16
lectures: 14
elaboration and examples (revision): 2

active teaching (practical): 40
auditory exercises: 15
laboratory exercises: 3
calculation tasks: 0
seminar works: 0
project design: 16
consultations: 6
discussion and workshop: 0
research: 0

knowledge checks: 19
check and assessment of calculation tasks: 0
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 0

references

Mass transfer and equipment

ID: MSc-1372
responsible/holder professor: Ivošević M. Miloš
teaching professor/s: Genić B. Srbislav, Ivošević M. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: process and environmental protection engineering

goals

Analysis of the mass transfer operations and apparatuses and assessment of their role in modern industry.

Understanding the most commonly used types of mass transfer apparatuses - their design and calculation procedures.

learning outcomes

The mastery of calculation procedures needed to analyze the mass transfer operations - the material balance, determination of the operational line and driving force.

The mastery of calculation procedures for sizing of the most commonly used mass transfer apparatuses.

theoretical teaching

Classification of mass transfer operations and basics principles of mass-transfer operations
General calculation procedure for mass transfer operations. Operation and equilibrium line, mass transfer driving force, number of transfer units, theoretical stage.
Mass transfer operations: distillation (continuous evaporation, single stage distillation, continuous condensation, distillation with deflegmation, differential distillation, fractional distillation, differential condensation), rectification, absorption, extraction, leaching, adsorption, drying.
Mass transfer apparatuses for gas-liquid systems, liquid-liquid and solid phase - fluid. Trayed and packed columns, drying chambers, etc.
Membrane mass transfer operations and and apparatuses.
Development trends in the field of mass transfer operations and apparatuses.

practical teaching

Examples of mass transfer operations. Mass and heat balancing. Determination of the operating line, driving force, the number of transfer units, the number of theoretical stages.

Examples of sizing of most commonly used mass transfer apparatuses: distillation column (with packing and with trays), extraction columns (with packing and with trays), adsorber (with a fixed layer of adsorbent), dryers (continuous and periodical).

Design procedures for membrane mass transfer operations and and apparatuses.

prerequisite

Defined in curriculum of the study program of the module.

learning resources

Jaćimović B., Genić S., Heat Transfer Operations And Equaipment, Part 1: Recuperative Heat Exchangers, Mašinski Fakultet Beograd, 2016.

Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.

Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.

number of hours: 75

active teaching (theoretical): 15
lectures: 13
elaboration and examples (revision): 2

active teaching (practical): 41
auditory exercises: 13
laboratory exercises: 2
calculation tasks: 10
seminar works: 0
project design: 10
consultations: 6
discussion and workshop: 0
research: 0

knowledge checks: 19
check and assessment of calculation tasks: 5
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 4
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references

Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.
Jaćimović B., Genić S., Heat Transfer Operations And Equaipment, Part 1: Recuperative Heat Exchangers, Mašinski Fakultet Beograd, 2016.

Mechanical and hydromechanical Operations and Equipment

ID: MSc-0991
responsible/holder professor: Obradović O. Marko
teaching professor/s: Obradović O. Marko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: process and environmental protection engineering

goals
The objective of the course is to students get theoretical and practical knowledge of common mechanical and hydromechanical processes and the associated equipment utilized in mineral processing. Course acquaints the students with characteristics of bulk solid materials and the basics techniques for bulk solid characterization. Mechanisms and basic principles of size reduction are covered. Subject gives overview of the main unit operations with respect to comminution (crushing and grinding) and screening/classification met in nowadays practice as well as equipment used in the unit operations. The combination of unit operations and equipment into circuits is also covered, as well the calculation of the basics characteristics of the equipment used.

learning outcomes
After completing the course the students are expected to able to calculate and use the curves for particle size distribution. Students shall know the most important unit operations in mineral processing, the mechanisms and principles of size reduction and methods used to classify particles according to their size and their characteristics. Student will be able to identify and select the equipment involved in a comminution circuit and calculate basics characteristics of the equipment. The students should know the principles for designing mineral processing circuits. After completing the course students will be capable to apply their knowledge in the real case studies of mineral processing and will have required background knowledge for mineral concentration processes.

theoretical teaching
1. Introduction to mechanical and hydromechanical operations, 2. Characteristics of size reduction processes, particle size and shape estimation, 3. Particle size analysis, sieve analysis, 4. Principles of comminution, comminution theory, 5. Crushing (basic principles, reduction ratio, crushers – types, constructions and operating principles, nip angle, critical operating speed, capacity, power consumption), 6. Grinding (basic principles, reduction ratio, types and construction of mills, operating principles, charge of mills – volume, types, wear etc, mill rotation and critical speed, mill capacity, mill power), 7. Comminution circuits (circulation load ratio, influence of circulation load ration on mill capacity, optimal value of circulation load ratio), 8. Screening (performance of screens, efficiency of screening, screening surfaces, probability of particle passage, kinetics of screening, screen types, factors affecting screen performance, screen capacity), 9. Classification (principles of classification, free settling, hindered settling, efficiency of separation, partition curve, air classifiers, cyclones, hydraulic classifiers – horizontal current classifiers, vertical current classifiers, centrifugal current classifiers (hydrocyclones), 10. Mixing

practical teaching
1. Characterization of particle size and shape, 2. Particle size distribution and sieve analysis, 3. Crushing – practical problems, 4. Grinding – practical problems, 5. Laboratory – sieve analysis, 6. Bulk material handling – transportation and feeding, 7. Screening – practical problems, 8. Classification – practical problems (air classifiers, cyclones, hydraulic classifiers), 9. Practical problem – calculation of industrial venting system (selection and cyclone dimensioning, pipeline calculation), 10. Mixing – practical problems

prerequisite
Obligatory subject of elective module Process engineering and environment protection.

learning resources
1. Bogner Martin: Mechanical operations, Naučna knjiga, Belgrade, 1987.

2. Bogner M, Stanojević M, Livo L: Cleaning and filtration of gasses and liquids, ETA, Belgrade, 2006.

3. Knežević Dinko: Mineral processing, University of Belgrade, Faculty of Mining and Geology, Belgrade, 2012.

4. Ćalić Nadežda: Principles of mineral processing, University of Belgrade, Faculty of Mining and Geology, Belgrade, 1990.

5. Magdalinović Nedeljko: Size reduction and classification, Nauka, Belgrade, 1999.

6. Laboratory installation for coal grindability testing and particle size distribution, Laboratory for Process Engineering

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 19
laboratory exercises: 2
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 9
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 3
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 10
final exam: 70
requirements to take the exam (number of points): 16

references

Barry A. Wills, Tim Napier-Munn: Mineral Processing Technology, Elsevier Science & Technology Books, 2006.
A. Gupta, D.S. Van: Mineral Processing Design and Operations - An Introduction, Elsevier, 2006.
R.P. King: Modeling and Simulation of Mineral Processing Systems, 2nd edition, Society for Mining, Metallurgy, and Exploration, Inc, 2012.
Warren McCabe, Julian Smith, Peter Harriot: Unit operations of chemical engineering, fifth edition, McGraw-Hill, 1993.
***: Basics in Minerals Processing, Metso Corporation, 2015.

Skill Praxis M - PTH

ID: MSc-1265
responsible/holder professor: Genić B. Srbislav
teaching professor/s: Genić B. Srbislav
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: process and environmental protection engineering

goals
The goal of course is to acquaint students with the resources, machines and devices used in various industries, especially in the food and pharmaceutical industry, chemical industry, oil refining, gas, non-metals and building materials, metallurgy, energy, communal activity. The practice should enable students to easily master the subject matter of vocational subjects.

learning outcomes
The successful completion of course students are introduced to: 1.processes and equipment used in the processing industry, 2. designing methods of processing plants, 3. test methods of processing plants and equipment, and others.

theoretical teaching
The role and importance of professional practice - process engineering, engineering in environmental protection. Basic principles of devices and machines of process equipment. Fundamentals of technological processes in the field of process engineering. The basics of designing process systems. The basics of distributions main and auxiliary fluids.

practical teaching
Organization and visits to factories of process industries. Understanding the specific technological processes and equipment in process industries through a review of technical documents and examining the situation in the factories. Analysis of technical documents (project and technical documentation) in the process industries.Technical control (audit) of technical documents - from compliance with documentation requirements of regulations and standards in the field of process industries. Introduce students to the measuring equipment used in the process industry by direct insight into condition of this equipment in factories and laboratories at its disposal department. The role of process engineers in the design and implementation of systems management processes and technologies.

prerequisite
Obligatory subject of elective module Process engineering and environment protection.

learning resources
Literature published by members of the Department of Process Engineering. Technical documentation. Cataloging documentation.

number of hours: 90

active teaching (theoretical): 10
lectures: 10
elaboration and examples (revision): 0

active teaching (practical): 70
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 70
project design: 0

consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 10

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 0
laboratory exercises: 30
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 25

references

Transport phenomena in process industry

ID: MSc-1056
responsible/holder professor: Stamenić S. Mirjana
teaching professor/s: Stamenić S. Mirjana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: process and environmental protection engineering

goals
Acquiring the necessary knowledge to understand the transport phenomena of heat and mass transfer in the process industry. Application of steady and unsteady heat and mass transfer in phases (two or more component fluids) in process equipment.

learning outcomes
The understanding of fundamentals of heat and mass transfer processes accompanied with multi-phase fluid flow. Estimation procedures for the intensity of heat and mass transport and pressure drop in chemical engineering.

theoretical teaching
Molecular transport phenomena. Newtons law of fluid friction, Fouriers law of heat conduction, Ficks law of molecular diffusion.

Steady and unsteady state heat and mass transfer in fluids.

Differential equations of of momentum, heat and mass convective transport. Laminar and turbulent flow.

Simplified models of convective transport. Analysis of heat and mass transfer resistances.Coefficients of Heat and mass transfer.

Similarity theory. Analogies between mass, heat and momentum transfer.

Mass transfer across a phase boundary. Inter-phase turbulence.

Simultaneous mass and heat transfer. Wet-bulb temperatures.

Boiling, condensation and thermal radiation. Typical cases in process equipment (heat exchangers, columns, furnaces).

Unsteady heat and mass transfer in solid phase.

Heat radiation.

practical teaching
Examples of steady and unsteady state molecular transport in fluids and solids
Examples of convective transfer.
Examples of application of the similarity theory - criterial equations
Examples of heat and mass transfer across a phase boundary.
Examples of simultaneous heat and mass transfer.
Laboratory: Wet-bulb temperature, coefficient of molecular diffusion
Examples of heat transfer with phase change: boiling, condensation
Examples of thermal radiation.
Examples of the unsteady heat and mass transfer in solid phase.
Examples of heat radiation.

prerequisite
Defined in curriculum of the module

learning resources
Resources are books listed within chapter - Literature

number of hours: 75

active teaching (theoretical): 22
lectures: 18
elaboration and examples (revision): 4

active teaching (practical): 34
auditory exercises: 17
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 19
check and assessment of calculation tasks: 2
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 10
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 5
calculation tasks: 15
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 31

references
Jaćimović B., Genić S., Heat Transfer Operations And Equipment, Part 1: Recuperative Heat Exchangers, Mašinski Fakultet Beograd, 2004.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.
Genić, S., Jaćimović, B., Jarić, M., Budimir, N., Process Fluid Properties, SMEITS, 2014.

Waste and wastewater management

ID: MSc-0125
responsible/holder professor: Jović M. Aleksandar
teaching professor/s: Jović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written+oral
parent department: process and environmental protection engineering

goals
In this course, students will gain a solid basic and specific knowledge in the field of waste management and wastewater management. Laboratory exercises give students the opportunity to solve the various practical problems and perceive gained theoretical knowledge.

learning outcomes
Knowledge that students acquired about the specific technical solutions, the choice of methods of use waste and wastewater treatment equipment enabling the assessment of basic principles relevant for the design of these plants.

theoretical teaching
Characteristics, management, Legal basis and strategy, Systems of collection, Separation and treatment, Incidence and equipment for waste collection, transfer stations, transport, separation at source, recycling,

Thermal processing procedures, a biological waste treatment products using waste processing,

Criteria for disposal, problems, control and treatment of leachate, generation and use of landfill gas, waste management future - legislation, collection, incineration, disposal,

Hazardous waste, remediation of contaminated soil,

Water resource management, Technological (process) characteristics, Planning, Legislation, Political influences, Future challenges,

Water demands, Requirements for water quality, Sources of water supply, Water treatment, Transfer (transport), distribution and storage of water, needs and future development,

Water pollution, Waste water collection, Treatment principles, Treatment plants,

Role of public and government in controlling pollution, Trends in controlling water pollution.

practical teaching
Calculation of the waste growth, determining the required capacity for the collection, calculation of waste composition,

Selection and sizing of equipment for waste treatment,

Selection and sizing of equipment for the factory for processing of municipal solid waste,

Determining the basic size of the landfille and landfill gas generation calculations and possibility of its using,

Calculation of concentration and flow of pollutants in and efficiency of equipment for the wastewater treatment,

Calculation of material and heat balance of devices for wastewater treatment and calculation of characteristic values,

Selection and sizing of equipment for wastewater treatment, Examples of plants for biological wastewater treatment,

Experimental determination of heat and material balance of devices for pyrolysis of waste,

Determining the effectiveness of the air distributor in the aeration devices for biological wastewater treatment.

prerequisite
There are no requirements to attend courses, in terms of the previously passed courses.

learning resources
Considering that for the course is not yet completed a textbook, materials for lectures are submitted to students in printed and electronic form.

Laboratory facility / installation / machine (LFI):

1. Laboratory testing facility for wastewater treatment

2. Laboratory plant for thermal waste treatment

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 13
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 2
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 20
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 27

references
Kuburovic, M., Jovovic, A., et al., Zastita zivotne sredine, chapter 15, p. 644-856., Termotehnicar, tom 2, Interklima, SMEITS, 2004., ISBN 86-82685-03-5

Jovovic, A., Karan, M., Petrovic, A.: Process and equipment in waste treatment systems, in: Developments of equipment in process and environmental engineering, 2000., p. 97-122, ISBN 86-7083-385-9
Stanojevic, M., Simic, S., Radic, D.,Jovovic, A, Аерација отпадних вода, теорија и прорачуни, ETA, Beograd, 2006., ISBN 86-85361-07-9

PRODUCTION ENGINEERING

Additive Manufacturing Technologies

ID: MSc-1314
responsible/holder professor: Popović D. Mihajlo
teaching professor/s: Pjević D. Miloš, Popović D. Mihajlo
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
Introduction to theoretical principles and practical skills in the field of designing technologies based on the adding material - additive technologies and their application to metal and polymeric materials. Furthermore, achievement of theoretical and practical knowledge from the design, calculation and construction of machining systems for additive manufacturing technologies based on modern technologies and optimal solution - natural construction methods and generative design.

learning outcomes
Upon successful completion of this course, students should be able to: • Recognize the basic differences between methods of material removal, material shaping and adding material (additive technologies) • Distinguish methods of additive manufacturing • Compare methods of additive manufacturing • Analyze the possibility of using additive technologies • Depending on the load of the structure and its purpose, they prescribe the appropriate type if additive technology, as well as modes of manufacturing • Generate a computer model of the work: CAD and scanning • Use generative methods (approaches) of designing based on natural method of construction • Optimize the geometry of the structure according to the conditions of additive technologies • Prepare for manufacturing • Design and calculate a processing system intended for additive manufacturing technologies.

theoretical teaching
Division of technologies; Basic concepts; The importance of Additive Manufacturing Technologies in modern development and production; Division of Additive Manufacturing Technologies; Additive production processes; 3D printing; Application (Production of prototypes, functional parts and tools); Techniques for forming 3D models using CAD tools and scanning; Natural construction method and generative design methods; Examples from industry, future directions of Additive Manufacturing Technologies development.

practical teaching
Laboratory practices with laboratory equipment in which the student gets acquainted with the practically realized processing systems for additive technologies. Introduction to the process of production of functional parts through the development of the project task. Computer simulations: Optimization of geometry, prescribing manufacturing technology base od additive manufacturing technologies, design of subsystems for the accompanying type of additive technology. Workshops: scanning of parts and processing in CAD packages. 3D printing. Rapid prototyping and rapid production of tools and accessories.

prerequisite
Defined by the study program / module curriculum.

learning resources
Filament extruder for 3D printer, 3D pen, FFF 3D printer, mSLA Creality LD-002R 3D printer, 3D scanner; Lectures in electronic form; Instructions for performing exercises in the laboratory; Instructions for project design; CAx workstations with appropriate software packages.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 40

references
Gibson I, Rosen W.D, Stucker B, Additive Manufacturing Technologies - Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010.
Gebhardt A, Heotter J.S, Additive Manufacturing, 3D Printing for Prototyping and Manufacturing, Hanser Gardner Publications, 2016.
Stritesky O, Prusa J, Bach M, Basics of 3D Printing with Josef Prusa, Prusa REsearch, Prague 2019.

Assembly systems

ID: MSc-0319
responsible/holder professor: Petrović B. Petar
teaching professor/s: Petrović B. Petar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals

1. Learning of systematic approach to the design and production of mechanical assemblies;

2. Understanding assembly process and basic assembly operations;

3. Impact of assembly process on product development – product structure and Design For Assembly techniques;

4. Part mating process, modeling and understanding relationships between precision, sensitivity and flexibility;

5. Basic concepts of assembly systems – manual, automatic and robotic systems; Assembly system design. Assembly workstation design issues;

6. Performance and Economics of Assembly Systems;

7. Product lifecycle and product disassembly.

learning outcomes

1. Understanding what is assembly, its role in production systems, and why it is important.

2. Fundamental knowledge and engineering skills about: assembly sequence analysis and design of assembly process, design of automatic part feeding and orienting, design for assembly (DFA) techniques, dimensioning and tolerancing of parts and assemblies, design of manual and automatic assembly workstations and systems, product disassembly and its impact on product lifecycle design.

theoretical teaching

Theoretical background of industrial assembly systems is given through 10 lectures + introductory lecture:

0. What is industrial assembly and its role in production systems,

1. Assembly system structure and assembly process,

2. Part mating theory of compliantly supported rigid parts,

3. Joining techniques and processes,

4. Feeding and material flow in assembly system,

5. Assembly structure, sequencing and Design For Assembly,

6. Manual assembly systems,

7. Automatic assembly systems – rigid transfer lines,

8. Automatic assembly systems – flexible assembly lines and robotic assembly cells,

9. Performance and Economics of Assembly Systems, and

10. Product lifecycle and disassembly technology.

practical teaching
Practical training is organized through laboratory exercises and project (team work) of assembly system design for selected product.

LAB 1: Quasi-static part mating – demonstration of passive compliant device RCC, demonstration of 6 DOF force/torque sensor, force sensor calibration, robot motion programming, measurement of part mating forces and identification of contact situations, comparison of experimentally evaluated results with theory.

LAB 2: Passive systems for feeding and orienting – vibratory bowl feeder and linear feeding tracks demonstration, part geometry analysis and identification of basic natural resting states, design and obstacles optimization of passive orienting system for selected class of headed cylindrical parts, tuning the system, measurement and efficiency estimation of configured orienting system, estimating of mean feeding capacity.

LAB 3: Vision systems for part feeding - demonstration of vision system configuration and its use in part feeding, image analysis and identification of paths contours and its locations, identification of system performances and optimization.

Project covers following topics: 1. Assembly design and product design for assembly (DFA), 2. Parts presenting systems - orientation, separation and positioning task, 3. Working heads for part mating, part joining and other assembly operations, and 4. Transfer systems - assembly conveying, manipulation operations, line balancing and control.

prerequisite
Fundamental knowledge on Manufacturing and Production Systems, Factory Automation, Robotics, Control Engineering

learning resources
[1] Petrović, P.B. 1998. Intelligent assembly systems - A contribution to the theory of assembly process, Book series of Intelligent technological systems, FME, Belgrade /In Serbian/;

[2] Handouts /In Serbian/;

[3] Instructions for laboratory report writing /In Serbian/;

[4] Instructions and project example /In Serbian/

[5] Instructions for handling the laboratory equipment /In Serbian/.

[6] Robotic cell equipped with sensory and acquisition system for demonstration of compliant part mating and RCC working principle;

[7] Experimental system based on linear vibratory conveyor for demonstration and students training in design of passive part presenting systems;

[8] Robotic welding system for demonstration of assembly joining operations based on welding and similar processes;

[9] Vision system for demonstration and students training in designing of flexible robotic part presentation systems;

[10] Experimental installation for demonstration of modern adhesion based joining technology (LOCTITE).

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 6
calculation tasks: 0
seminar works: 0
project design: 16
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 15
final exam: 40
requirements to take the exam (number of points): 30

references
Ćosić., I., Montažni sistemi, IP Nauka, Beograd, 1991, ISBN: 86-7621-045-4.
Boothroyd, G. 1983. Design for Assembly Handbook, Design project, Dep. Of Mechanical Eng., University of Massachusetts, Amherst, Massachusetts, USA.
Bothroyd, G., Poli, C. and Murch, L. E. 1982. Automatic Assembly, Marcel Dekker Inc., New York, USA, ISBN 0-8427-1531-4.
Whitney, E., D., Mechanical Assemblies: their Design, Manufacture, and Role in Product Development, Massachusetts Inst. of Techn, New York Oxford, OXFORD UNI PRESS, 2004, ISBN 0-19-515782-6
Nof, S. Y., Wilhelm, W. E. and Warnecke, H. J. 1996. Industrial Assembly, Chapman & Hall, London, GB, ISBN 0-412-55770-3.

Computer Control and Monitoring in Manufacturing Automation

ID: MSc-0787
responsible/holder professor: Petrović B. Petar
teaching professor/s: Petrović B. Petar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: production engineering

goals
Acquisition of knowledge about the application, design and introduction of modern computer control systems and supervisory into manufacturing automation. Skill development for solving computer control nad supervisory problems by using computer, information and control technologies and adequate scientific methods.

learning outcomes
The student should:

1. Uderstand the principles, place and role of the computer control system and supervisoring in manufacturing automation, link knowledge of related subjects to apply it to control and supervisoring in manufacturing automation;

2. Master scientific methods of analysis, synthesis, design and introduction of computer control systems in manufacturing automation;

3. Know practical problem-solving and how to apply computer technology and modern control systems in control and supervisoring in manufacturing automation.

theoretical teaching
1.Computer control systems in manufacturing automation. CNC, robot controllers, programmable controllers, programmable automation controllers and computers.

2. CNC control. Functions, hardware, software, mathematical models. Main and auxiliary movement control, interpolation and internal calculations. Control panel and workshop programming. Communication functions.

3. Programmable controllers. Functions, hardware, software, input/output modules. Programming languages and programming techniques according to the IEC 61131 standard.

4. SCADA systems. Functions, hardware, software. Data acquisition, man-machine interface, programming and algorithms in control and monitoring.

5. Sensors and actuators in control and supervisoring. Remote and intelligent terminal units.

6. Modern computer control systems and open-architecture control systems. Communication networks. Distributed control systems in manufacturing automation and IEC 61499.

practical teaching
1.Auditorial exercises: Tasks in control design and supervisoring in manufacturing automation, with programming and control scheme design.

2. Laboratory exercises: Design of examples for control and supervisoring in manufacturing automation and their practical realization in laboratory conditions, with the use of modular robots and computer-based control systems, CNC control, programmable controllers, robot controllers and SCADA software, with programming.

3. Project: Design of examples for control and supervisoring in manufacturing automation, with programming.

prerequisite
Defined by curriculum of study program.

learning resources
1. Pilipović, M. Control and monitoring in manufacturing automation - Handouts, FME, Belgrade, 2011, DVL

2. Pilipović M., Manufacting processes automation: Laboratory, FME, Belgrade, 2006, PRA. /In Serbian/

3. Lab desk with pneumatic, electro-pneumatic and electric components and programmable controllers, Lab for manufacturing automation, EOP/LRS.

4. "Pick and Place" electro-pneumatic modular robots with programmable controllers, Lab for manufacturing automation, EOP/LPI.

5. Programming computers, Lab for manufacturing automation, IKT/PPC.

6. Software for programmable controller programming, Lab for manufacturing automation, IKT/RRO.

7. Communication network of computers and programmable controllers, Lab for manufacturing automation, IKT/KIO.

8. CNC and robot controllers, Lab for machine tools, EOP/LPI

9. SCADA software for supervisoring and programming, Lab for manufacturing automation, IKT/RRO.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 20
laboratory exercises: 15
calculation tasks: 0

seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 36

references

Mikell P. Groover, Automation, Production Systems, and Computer Integrated Manufacturing, Prentice-Hall, Inc. 1987.
David Bailey, Edwin Wright, Practical Scada for Industry, Esevier, 2003.
Yoram Koren, Computer Control of Manufacturing Systems, McGraw-Hill Book Company, 1983.
Informatika: INFO 73 Programmable Controllers, Programming Guide, Informatika, Belgrade, 2011.
Informatika, InfoControl SCADA - User Guide, Informatika, Belgrade, 2011.

Computer Integrated Manufacturing Systems and Technology

ID: MSc-0665
responsible/holder professor: Babić R. Bojan
teaching professor/s: Babić R. Bojan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: production engineering

goals
A detailed study of the principles and application of computer integrated manufacturing. Advanced concepts and models related to computer-aided design, computer-aided process planning, computer aided manufacturing, production planning and scheduling.

learning outcomes
This course will enable the student to:

• apply knowledge of modeling, simulation and visualization in industrial applications,

• design CIM systems that satisfy the given conditions,

• identify and solve problems in the operation of the CIM system,

• improve the performance of manufacturing systems using different CIM concepts and tools,

• handle production data and the different software used in production.

theoretical teaching
1. Introduction to CIM

2. Computer-aided Design

3. Automated Manufacturing Equipment

4. Group Technology And Computer-aided Process Planning

5. Shop Floor Control and Introduction of FMS

6. Production Planning and Control

7. Cim Implementation and Data Communication

practical teaching
Laboratory work includes computer-aided applications and programming of automated production equipment.

prerequisite
Defined by curriculum of study programme/module.

learning resources
(1) B. Babic, Computer integrated systems and technologies, University of Belgrade, Faculty of Mechanical Engineering, 2017

(2) B. Babic, Software "Moodle" for distance learning (http://147.91.26.15/moodle/), University of Belgrade, Faculty of Mechanical Engineering, 2012

(3) AnyLogic simulation software

(4) B. Babic, Software packages for process planning

(5) B. Babic, Process planning, University of Belgrade, Faculty of Mechanical Engineering, 2006

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 8
calculation tasks: 3
seminar works: 0
project design: 15
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 2
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 15
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 35
final exam: 30
requirements to take the exam (number of points): 30

references
Groover, M. P., Automation, Production Systems, and Computer-Integrated Manufacturing, 3rd Ed. Pearson Education, 2008
B. Babic, Computer integrated systems and technologies, University of Belgrade, Faculty of Mechanical Engineering, 2017

Computer Simulation in Manufacturing Automation

ID: MSc-0722
responsible/holder professor: Jakovljević B. Živana
teaching professor/s: Jakovljević B. Živana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The objective of this course is that students: acquire knowledge and skills necessary for practical problems solving in manufacturing automation using computer simulation; to master the methods used for computer simulation modeling and implementation in manufacturing automation; to obtain the knowledge about the systematic approach to the project of computer simulation in manufacturing automation; to develop critical approach to the effects of computer simulation application in automation; to get familiar with the role of computer simulation within digital factory.

learning outcomes
After successfully completing this course, the students should be capable to:

- Create and implement stochastic simulation;

- Create conceptual model for discrete event simulation;

- Create and implement discrete event simulation within fixed and flexible automation framework;

- Create conceptual and computer model for continuous simulation of various processes;

- Integrate continuous and discrete event simulation;

- Manage discrete event simulation project.

theoretical teaching
1. Introduction to computer simulation: simulation objectives; advantages and disadvantages of simulation; phases of computer simulation development; computer simulation in manufacturing automation; a variety of simulation models: continuous and discrete models, deterministic and stochastic simulation

2. Stochastic simulation: sampling methods, random numbers, random number generators, Monte Carlo simulation

3. Discrete event simulation: elements of discrete event simulation, conceptual modeling of discrete event simulation, activity cycle diagram

4. Computer models for discrete event simulation: approaches in model coding: activity based approach, event based approach, process based approach, the three phase approach; comparative analysis of different approaches

5. Discrete event simulation software: general purpose programming languages, application oriented simulation software; definition of simulation model in programming languages and simulation software packages; simulation outputs and results presentation; application of computer graphics and animation in simulation; application examples of simulation software

6. Discrete event simulation application in automation: generation of conceptual and computer models of fixed, programmable and flexible automation

7. Discrete event simulation project: system definition, generation of simulation model, model verification and validation, simulation experiments, results presentation and documentation

8. Continuous system simulation: continuous systems modeling, basic principles of numerical integration, modeling of the examples of continuous systems in manufacturing automation, programming languages and software for continuous system simulation, integration of continuous simulation into discrete event simulation

9. Digital factory and simulation: concept and models of digital factory; the role of simulation in digital factory: plant design and optimization, operational management and optimization

practical teaching
Laboratory exercises:

1. Monte Carlo simulation

2. Discrete event simulation software: ARENA – basic functioning principles and simulation examples

3. Discrete event modeling and simulation: examples of fixed and flexible automation

4. Continuous systems simulation: modeling and simulation of specific examples in the area of manufacturing automation using general purpose programming language and in application oriented simulation software – ARENA

Discrete event simulation project:

Students work on project dealing with the development of a simulation of a chosen flexible manufacturing system. During project realization students systematically implement all phases of discrete event simulation project: conceptual modeling, model coding, animation generation, model verification and validation, experimentation, analysis of the simulation results. The output is the report and project presentation at the end of semester.

prerequisite
none

learning resources
Jakovljevic, Z., Computer simulation in manufacturing automation – lecture handouts

Computer classroom – each student individually works on a computer

Arena Simulation Software by Rockwell Automation

General purpose programming language

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 20
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0

check and assessment of projects: 1
colloquium, with assessment: 0
test, with assessment: 8
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 30
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 30

references

Carrie, A., Simulation of Manufacturing Systems, John Willey and Sons, New York, 1988
Robinson, S., Simulation: The Practice of Model Development and Use, John Willey and Sons, New York, 2004
Pidd, M., Computer Simulation in Management Science, John Willey and Sons, New York, 2004
Kelton, D., V., et al., Simulation with Arena, McGraw-Hill, 2009
Cellier, F., E., Kofman, E., Continuous System Simulation, Springer, New York, 2006

Coordinate Measuring Machines

ID: MSc-1166
responsible/holder professor: Stojadinović M. Slavenko
teaching professor/s: Stojadinović M. Slavenko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The objective of the course is acquire of knowledge and skills in the field of coordinate metrology and flexible metrological automation for solving metrological problems primarily in production engineering, and then in other engineering disciplines. Students should acquire and to master new knowledge and skills abouth: basic terms, development and application of coordinate measuring machine (CMM) in engineering practice; subsystems of CMM; accuracy and methods of accuracy testing; measuring and inspecting all types of tolerances through the definition of the measurement protocol, the configuration and calibration of measuring sensors; methods of automatic inspection planning and simulation of measurement.

learning outcomes
After successfully completion of this course, the students should be capable to: recognize the structure and characteristics of the CMM subsystem with their functions; determine the CMM coordinate systems and define the inspection and measurement plan (determine the sequence of metrological tasks with the configuration of the measurement sensor and perform the analysis from the geometric-metrological aspect); determine the CMM error budget and perform its analysis; take tolerances from the CAD geometric model, simulate measurement and output from the simulation used in the CMM programming system (geometric-metrological identification); analyze the report on the results of measurement and inspection; make CMM selection for the conditions of use (group of metrology tasks) in the production organization.

theoretical teaching
Theoretical teaching embraces ten units: 1. Introduction to measuring machines. Basic characteristics. Development and application of CMM. Presentation of measuring machines of the latest-fifth generation. 2. Hardware structure of CMM. 3. Software for general and special purpose, its characteristic and applications. 4. Programming CMM. Off / on - line programming. 5. Accuracy and accuracy testing of CMM. Standards for accuracy testing of CMM. 6. Automatic inspection planning on CMM. Metrological model of part and metrological features. 7. Optimization of the planned measuring path. 8. Configuring measuring probes and analyzing the setup of measuring parts. 9. Measurement and inspection planning . Measuring protocol. 10. Simulation of measurement and generation of a control data list.

practical teaching
Practical teaching embraces ten units: seven auditory and three laboratory exercises, as well as seminar work. The content of the auditory exercises is as follows: 1. Measurement and inspection. Determination of the coordinate measurement system. 2. Definition of geometric and metrological features. 3. Distribution of measuring points by metrological features depending on the type of tolerance. 4. The principle of the collision avoidance. 5. Generating the initial path of the measurement sensor during inspection of prismatic parts on CMM. 6. Generating the optimal path of the measuring sensor on the base an ants colony optimization technique. 7. Analysis of setup of measuring parts and measuring bases.

Laboratory exercises are realized by factory visit and work in the PTC-Creo (CMM-module) software for modeling and simulation, as a followed: 1. Visit to the factory that owns CMM and get familiar about its work and technical characteristics. 2. Modeling and simulation of measurements in the software system PTC Creo - CMM module. 3. Inspection planning in PTC Creo - CMM module for a concrete measuring part. Generating CL files of a measuring sensor.

prerequisite
Defined by curriculum of study programme.

learning resources
1. Handouts for each lecture.

2. The instruction for doing laboratory exercises, tasks and seminar work.

3. The monograph in the field of quality and production metrology.

4. The web site of the course with addresses of leading organizations and important institutions in this area (under preparation).

5. Facility and technical equipment: Laboratory for production metrology and TQM.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 9
calculation tasks: 3
seminar works: 4
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 1
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 20
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Stojadinovic, S., (2018), Handouts for each lecture.
Stojadinovic, M.S., Majstorovic, D. V. (2019), An Intelligent Inspection Planning System for Prismatic Parts on CMMs, Springer International Publishing, 978-3-030-12806-7.

Majstorovic, V., Hodolic, J., Coordinate Measuring Machine, FTN Novi Sad
Sladek, A. J., Coordinate Metrology - Accuracy of Systems and Measurements, Springer Verlag Berlin Heidelberg
Smith, G. T. (2013). Industrial metrology: surfaces and roundness. Springer Science & Business Media.

Decision-making methods

ID: MSc-0302
responsible/holder professor: Miljković Đ. Zoran
teaching professor/s: Miljković Đ. Zoran, Petrović M. Milica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: production engineering

goals

The aim of the course is to train the students to make decisions in the process of product development and design by using mathematical-algorithm-based procedures and artificial intelligence techniques. Development of students' creative abilities in improving technical/technological characteristics of a product using methods based on conceptual design points out the optimum decision function based on intelligent agents.

learning outcomes

Students' learning outcomes of this course are:

• The complex use of IC technologies in decision-making.
• The implementation of developed software (MATLAB, BPnet, ART Simulator, AnyLogic, TRIZ, Flexy) in solving typical technological problems within decision-making methods based on paradigms of artificial intelligence.
• Autonomous selection of the methods based on application of artificial neural networks and genetic algorithms in seeking the optimal solution in the process of product development.
• Understanding the interaction of soft and hard real-time subsystems of mobile robot in decision-making during exploring by using reconfiguration of physical structure and intelligent behaviour programming in MATLAB.
• Capability for team work.

theoretical teaching

Introduction to the theory of decision-making; intelligent systems. Systems for design and selection of solutions. Hybrid intelligent manufacturing systems; decision-making methods based on intelligent agents. Decision-making based on paradigms of artificial intelligence. Artificial neural networks; neuron - a processing element, transfer function (activation), architecture, learning algorithms. Application of artificial neural networks in decision-making. Genetic algorithms. Manufacturability of the product, process planning optimization. Intelligent machines and decision-making. Development of advanced technologies for the 21st century.

practical teaching

Conceptual design and decision-making variables (selected examples). Analysis of typical manufacturing problems in domain of decision-making (laboratory work). Algorithms of machine learning and knowledge-based presentation - decision tree induction. Software for simulation of artificial neural networks (laboratory work). Manufacturability of the product - design parameters based on material flow for chosen manufacturing process (programming in MATLAB); application of genetic algorithms in optimization (selected examples). Machine learning of material flow for chosen manufacturing process. Intelligent machines and decision-making (programming in MATLAB) - reconfigurable mobile robots and machine learning (laboratory work). Examples of conceptual designed products with optimal performances, pointing out the application of advanced production technologies (project activities). Project design (design parameters, searching performances, and defining of a decision matrix and decision function).

prerequisite
Defined by Curriculum.

learning resources
[1] Z. Miljković, M.M. Petrović, INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and artificial intelligence, Textbook, XXVIII+409 p., Univ. of Belgrade - Faculty of Mechanical Engineering, 2021 (I edition), 18.1 /In Serbian/

[2] Z. Miljković, D. Aleksendrić, ARTIFICIAL NEURAL NETWORKS – solved examples with theoretical background (2nd ed.), Textbook, Univ. of Belgrade - Faculty of Mechanical Engineering, 2018, 18.1 /In Serbian/

[3] Z. Miljković, SYSTEMS OF ARTIFICIAL NEURAL NETWORKS IN PRODUCTION TECHNOLOGIES, Monograph book within the Series Intelligent Manufacturing Systems, Vol. 8, Univ. of Belgrade - Faculty of Mechanical Engineering, 2003, 18.1 /In Serbian/

[4] V.R. Milačić, MANUFACTURING SYSTEMS DESIGN THEORY, Monograph book within the Series Intelligent Manufacturing Systems, Vol. 2, Univ. of Belgrade - Faculty of Mechanical Engineering, 1987, 18.1 /In Serbian/

[5] Z. Miljković, M.M.Petrović, Handouts, Univ. of Belgrade - Faculty of Mechanical Engineering, 2020, 18.1 /In Serbian/

[6] Z. Miljković, M.M.Petrović, Software "Moodle" for distance learning (http://147.91.26.15/moodle/), Univ. of Belgrade - Faculty of Mechanical Engineering, 2020, 18.13

[7] Z. Miljković, M.M.Petrović, Website for Decision-making methods (http://cent.mas.bg.ac.rs/), Univ. of Belgrade - Faculty of Mechanical Engineering, 2020, 18.13

[8] Z. Miljković, Software packages for simulation of artificial neural networks - BPnet, ART Simulator, MATLAB; Laboratory CeNT website: http://cent.mas.bg.ac.rs/, Univ. of Belgrade - Faculty of Mechanical Engineering, 18.13

[9] Laboratory mobile robot prototype (Khepera II mobile robot with gripper and camera; LEGO Mindstorms NXT and EV3 Sets of reconfigurable mobile robots equipped with sensors and microcontrollers), Laboratory CeNT, Univ. of Belgrade - Faculty of Mechanical Engineering, 18.12

[10] Laboratory model of designed manufacturing system, Laboratory CeNT, Univ. of Belgrade - Faculty of Mechanical Engineering, 18.12

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 2
laboratory exercises: 16
calculation tasks: 0
seminar works: 0
project design: 7
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0

check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 2
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 25
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 35
final exam: 30
requirements to take the exam (number of points): 30

references

Y. Hatamura, (2006) DECISION-MAKING IN ENGINEERING DESIGN, Springer-Verlag London Limited, Printed in Germany.
J. N. Siddall, (1972) ANALYTICAL DECISION-MAKING IN ENGINEERING DESIGN, Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
N.P. Suh, (2001) AXIOMATIC DESIGN - ADVANCES AND APPLICATIONS. New York.:Oxford University Press.; N.P.Suh, (1990) THE PRINCIPLES OF DESIGN, Oxford University Press.
E. Alpaydin, (2010) INTRODUCTION TO MACHINE LEARNING, 2nd Edition, The MIT Press, Cambridge, England.; E. Alpaydin, (2004) INTRODUCTION TO MACHINE LEARNING, The MIT Press, Cambridge, England.
R. R. Murphy, (2000) INTRODUCTION TO AI ROBOTICS, A Bradford Book, The MIT Press, Cambridge, Massachusetts London, England.

Industrial robots

ID: MSc-1106
responsible/holder professor: Miljković Đ. Zoran
teaching professor/s: Miljković Đ. Zoran, Slavković R. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The student should acquire fundamental knowledge of industrial robots (basic subsystems, their functioning variants and realization), knowledge needed for robot design, robotized workplaces design, robot programming, intelligent behaviour as well as develop capability for further dealing with subject matter in domain of robotics.

learning outcomes
After completed this course the students should be able to:

•Understand the role and importance of industrial robots application (effects on productivity, flexibility, product quality and humanization of work).

•Solve the problem of robot introducing to the plant/factory.

•Select appropriate robot configuration, end-effector and peripheral equipment for given technological task.

•Design robotized workplace taking into account cycle time analysis as well as techno-economic analysis (pay back analysis).

•Programming the robots as well as robotized cell.

•Design the basic manipulator mechanical subsystems as well as select the appropriate components.

theoretical teaching
New teaching contents:

1. Definitions, functional structure of a robot with subsystem
description, classification.
2. Robot kinematics: spatial descriptions and transformations, direct and inverse kinematics problem.
3. Robot control. Control system structure. Single axis control (drive and measuring system, transmission system). Industrial robot control system (PTP and CP). Intelligent control.
4. Sensors, internal and external. End effectors, grippers and tools.
5. Robot programming, methods. Robot programming languages.
6. Robot application. Robot cell layouts and cycle time analysis. Manipulation and processing tasks, assembly, techno-economic analysis.

Explanations of new teaching contents:
1. Robot mechanical structure – manipulator. Mobile robots - specifications and types.
2. Description of orientation. Algorithm of associating coordinate systems to robot segments. The Jacobian.
3. Recognition systems.
4. Artificial intelligence within advanced robotic systems.

practical teaching
Practical teaching involves all necessary types of exercises.

1. Five auditory exercises: Kinematics of manipulators. Analysis of drive systems, measuring systems, transmission systems. End effectors. Robot programming. Robot application.

2. Four calculation tasks: Spatial relations and transformations. Robot kinematics and cycle time analysis. Three home-works relates to all these areas.

3. Three laboratory exercises: Robot kinematic (mechanical) structure – manipulator. Drive systems, measuring systems and transmission systems. Robot programming.

4. Seminar work: robot kinematics, programming, cycle time analysis.

prerequisite
Study curriculum and student motivation for knowledge acquisition in domain of industrial robots according to the goals set and outcomes offered.

learning resources
1. Textbook: (2017) INDUSTRIAL ROBOTS by D. Milutinović. (in preparation)/In Serbian/ University of Belgrade - Faculty of Mechanical Engineering.

2. Textbook: (2021) Z. Miljković, M.M. Petrović, INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and artificial intelligence, (I edition), Textbook, XXVIII+409 p., /In Serbian/ University of Belgrade - Faculty of Mechanical Engineering.

3. D. Milutinović, Z. Miljković, N. Slavković, Handouts for each lecture. /In Serbian and English/

4. Z. Miljković, N. Slavković, Instructions for doing students' tasks, laboratory exercises and seminar work. /In Serbian and English/

5. Z. Miljković, N. Slavković, The Course site (http://cent.mas.bg.ac.rs/nastava/ir_msc/index.htm) containing relevant information for students, book references as well as addresses of robot manufacturers and respective institutions (IFR, RIA, JARA, CIRP, etc.).

6. Craig J.J. (1989) Introduction to Robotics: Mechanics and Control, Addison Wesley.

7. Sciavicco L., Siciliano B., (2005) Modelling and Control of Robot Manipulators, Springer.

8. Dudek G., Jenkin M., (2010) Computational Principles of Mobile Robotics, 2nd ed., Cambridge University Press.

9. Connell J.H., (1990) Minimalist Mobile Robotics - A Colony-style Architecture for an Artificial Creature, Academic Press.

10. Angeles J., (2007) Fundamentals of Robotic Mechanical Systems, 3rd ed., Springer.

11. Facility: Laboratory for industrial robotics and artificial intelligence with four industrial robots, ten mobile robots equipped with sensors and microcontrollers, six cameras, software for simulation and programming WORKSPACE 5, 3D printer as well as educational means.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 13
laboratory exercises: 8
calculation tasks: 8
seminar works: 1

project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 1
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Niku S.B. (2001) Introduction to Robotics: Analysis, Systems, Applications, Prentice Hall.
Fu K.S., Gonzales R.C., Lee C.S.G. (1987) Robotics: Control, Sensing, Vision, and Intelligence, McGraw-Hill, New York.
Groover P.M., Weiss M., Nagel R.N., Odrey N.G. (1987) Industrial Robotics: Technology, Programming and Applications, 2nd Ed., McGraw-Hill, New York.
Pires M.J. (2007) Industrial Robot Programming, Springer.
McKerrow P.J. (1991) Introduction to Robotics, Addison Wesley.

Intelligent manufacturing systems

ID: MSc-0131
responsible/holder professor: Miljković Đ. Zoran
teaching professor/s: Miljković Đ. Zoran, Petrović M. Milica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: production engineering

goals

The aim of the course is to develop students' ability for conceptual design and implementation of intelligent manufacturing systems and processes by using the design theory, machine learning and evolutiveness, based on paradigms of artificial intelligence (AI). After he/she becomes familiar with the structure of intelligent manufacturing system based on multi-agent methodology (agents: robot, machine tool, machine learning, process planning, optimization, software, etc.) using laboratory equipment like reconfigurable mobile robots with sensors and laboratory model of designed manufacturing system as well as simulation by applying specialized software tools, the student will acquire knowledge necessary for the development of advanced production technologies.

learning outcomes

Students' learning outcomes of this course are:

• Implementation of developed software tools (e.g. TRIZ, Flexy) for modelling and analysis of intelligent manufacturing systems and processes.

• Selection of methods based on the application of artificial neural networks (by using software packages MATLAB, BPnet, ART Simulator) and other computational intelligence techniques in designing and building intelligence of artefacts (autonomous mobile robots can thus be observed interacting with their manufacturing environment) as well as scheduling of manufacturing entities.

• Advanced utilization of the software for discrete event simulation (AnyLogic, Flexy) with analysis and presentation of the experimental results obtained.

• Understanding the interaction of soft and hard real-time subsystems of autonomous mobile robot through reconfiguration and advanced programming in MATLAB.

• Capability for team work.

theoretical teaching

Introduction to knowledge and machine learning-based intelligent systems. Machine learning models; deduction, induction and analogy. Machine learning as a basis of intelligent systems and processes. Paradigms of AI; decision tree induction, artificial neural networks, genetic algorithms, case-based reasoning-CBR (learning from experience), etc. Evolutiveness and intelligent systems based on Multi-agent Systems Engineering (MaSE) methodology. Agents work autonomously; basic concepts and importance. Autonomous mobile robots; target cognitive capabilities of mobile robots including perception processing, collision avoidance, anticipation, path planning, complex motor coordination, reasoning about other agents, etc. Mobile robot localization and navigation (pose estimation) as well as characteristic objects detection in robotic exploration within the manufacturing environment. The design theory and development of intelligent manufacturing systems. Scheduling of manufacturing entities. Software tools for modelling and analysis of intelligent manufacturing systems. Conceptual design of typical FMS lay-out configurations (FMS-Flexible Manufacturing System). Examples of developed Intelligent Manufacturing Systems (IMS).

practical teaching
Modelling and analysis of intelligent manufacturing systems and processes (laboratory work). Exemplified application of developed intelligent systems (laboratory work). Software for simulation of artificial neural networks (laboratory work). Software architectures for machine learning of intelligent systems. Intelligent behaviour of manufacturing system agents based on empirical control algorithm. Subsumption architecture for intelligent control based on achieving increasing pre-specified levels of competence in an intelligent robotic system (intelligent behaviour design of an autonomous mobile robot interacting with detected objects - programming in MATLAB). Scheduling plans optimization using genetic algorithms (programming in MATLAB). Software tools for conceptual design of FMS lay-out configurations (laboratory work). Project design (Material handling; Intelligent control of autonomous mobile robot; Scheduling of indoor transportation equipment).

prerequisite
Defined by Curriculum.

learning resources
[1] Z. Miljković, M.M. Petrović, INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and artificial intelligence, Textbook, XXVIII+409 p., University of Belgrade - Faculty of Mechanical Engineering, 2021 (I edition), 18.1 /In Serbian/

[2] Z. Miljković, D. Aleksendrić, ARTIFICIAL NEURAL NETWORKS – solved examples with theoretical background (2nd ed.), Textbook, University of Belgrade - Faculty of Mechanical Engineering, 2018, 18.1 /In Serbian/

[3] M. Kalajdžić (editor), Lj. Tanović, B. Babić, M. Glavonjić, Z. Miljković, et al., CUTTING TECHNOLOGY (8th ed.), Handbook, University of Belgrade - Faculty of Mechanical Engineering, 2017, 18.1 /In Serbian/

[4] Z. Miljković, Systems of artificial neural networks in production technologies, Monograph book within the Series Intelligent Manufacturing Systems, Vol. 8, University of Belgrade - Faculty of Mechanical Engineering, 2003, 18.1 /In Serbian/

[5] Z. Miljković, M.M. Petrović, Handouts, University of Belgrade, Faculty of Mechanical Engineering, 2020, 18.1 /In Serbian/

[6] Z. Miljković, M.M. Petrović, Software "Moodle" for distance learning (http://147.91.26.15/moodle/), University of Belgrade - Faculty of Mechanical Engineering, 2020, 18.13

[7] Z. Miljković, M.M. Petrović, Website for IMS (http://cent.mas.bg.ac.rs/), University of Belgrade - Faculty of Mechanical Engineering, 2020, 18.13

[8] Laboratory mobile robot prototype (Khepera II mobile robot with gripper and camera; LEGO Mindstorms NXT and LEGO Mindstorms EV3 Sets of reconfigurable mobile robots equipped with sensors and microcontrollers), Laboratory CeNT, University of Belgrade - Faculty of Mechanical Engineering, 18.12

[9] Laboratory model of designed manufacturing system, Laboratory CeNT, University of Belgrade - Faculty of Mechanical Engineering, 18.12

[10] Software packages (MATLAB, BPnet, ART Simulator, AnyLogic, TRIZ, Flexy), Laboratory CeNT, University of Belgrade, Faculty of Mechanical Engineering, 18.13

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 2
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 20
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 35
final exam: 30
requirements to take the exam (number of points): 30

references
R.Siegwart,I.R.Nourbakhsh,D.Scaramuzza, (2011) INTRODUCTION TO AUTONOMOUS MOBILE ROBOTS, 2nd Edition, The MIT Press; R.Siegwart,I.R.Nourbakhsh, (2004) INTR. TO AUTONOMOUS MOBILE ROBOTS, The MIT Press.
J. Banks, J.S. Carson, B.L. Nelson, D.M. Nicol, (2005) DISCRETE EVENT SYSTEM SIMULATION, 4th Edition, Pearson Education International Series.
N.P. Suh, (2001) AXIOMATIC DESIGN - ADVANCES AND APPLICATIONS. New York.:Oxford University Press; N.P. Suh, (1990) THE PRINCIPLES OF DESIGN, Oxford University Press.
E. Alpaydin, (2010) INTRODUCTION TO MACHINE LEARNING, 2nd Edition, The MIT Press, Cambridge, England.; E. Alpaydin, (2004) INTRODUCTION TO MACHINE LEARNING, The MIT Press, Cambridge, England.
R.R. Murphy, (2000) INTRODUCTION TO AI ROBOTICS, The MIT Press, Cambridge, England.

Machine tools M

ID: MSc-0920
responsible/holder professor: Kokotović M. Branko
teaching professor/s: Živanović T. Saša, Kokotović M. Branko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
1. To develop ability to perceive typical missions of machining systems.

2. To study machine tools mechanisms and systems for their control and programming.

3. To receive training in testing procedures for machine tools.

4. To develop ability to analyze complex machine tools and machining systems equipment.

5. The develop ability to analyze the resources for machine tools development.

6. To study configuring and/or building of machine tools for planned mission.

7. To receive training for realization of one mission of machine tools through writing the seminar work.

8. To know how to make technical projects.

learning outcomes
Upon successful completion of this course students should be able to:

1. Recognize typical missions of manufacturing systems.

2. Apply basic types of machine tool mechanisms in their design.

3. Configure the control of CNC machine tools based on systems with open architecture.

4. Program new generation machine tools using different programming methods.

5. Evaluate the quality of machine tools and machining system based on applied standard test procedures.

6. Configure mechine tool for their own needs.

7. Apply the acquired knowledge on the available resource for the development and / or improvement of machine tools and manufacturing systems.

8. Prepare Technical Elaborate and reports about testing and programming of machine tools.

theoretical teaching
New teaching contents:

1. AH-1 Consolidation of the curriculum for Machine Tools M.
2. AN-2 Machine tools mechanisms.
3. AN-3 Configuring machine tools.
4. AN-4 Open-architecture machine tools control.
5. AN-5 Object programming of machine tools.
6. AN-6 Testing of machine tools and machining systems.
7. AN-7 Complex machine tools.
8. AN-8 Machine tools and machining systems equipment.
9. AN-9 Resources for machine tools and machining systems development.

Extension:

1. AR-1 Extension of the theme AN-2 using the examples of support structures, guides, leading spindle etc.
2. AR-2 Extension of the theme AN-3: Methods of configuring new machine tools.
3. AR-3 Extension of the theme AN-4: The EMC2 System for machine tools control.
4. AR-4 Extension of the theme AN-5: The STEP-NC Protocol for programming machine tools.
5. AR-5 Extension of the theme AN-6: Examples of complete procedures for testing machine tools.

practical teaching

1.Auditorial exercises:

(1)Resources for studying machine tolls. (2)Plan and program of laboratory exercises.

2. Laboratory exercises:

(1)Machining system static stiffness. (2)Testing lathe accuracy. (3)Working accuracy of numerically-controlled milling machines. (4)Circular interpolation test, or, One combined testing of machining system.

3. Seminar work.

prerequisite

Study curriculum and student motivation for learning about machine tools and machining

systems according to the goals set and outcomes offered.

learning resources

1. N.N, Visionary Manufacturing Challenges for 2020, National Academy Press, Washington, D.C. 1998, ISBN 0-309-06182-2.

2. W. R. Moore, Foundations of Mechanical Accuracy, The Moore Special Tool Company, First Edition, Third Printing, 1999.

3. X. Xu, A.Y.C. Nee, Advanced Design and Manufacturing Based on STEP, Springer, 2009, ISBN 978-1-84882-738-7.

4. D. Zhang, Parallel Robotic Machine Tools, Springer, 2010, ISBN 978-1-4419-1116-2.

5. W. A. Khan, A. Raouf, K. Cheng, Virtual Manufacturing, Springer, 2011, ISBN 978-0-85729-185-1.

6. H. A. ElMaraghy (Ed), Changeable and Reconfigurable Manufacturing Systems, Springer,2009, ISBN: 978-1-84882-066-1.

7. K. Apro, Secrets ot 5-Axis Machining, Industrial Press, 2008, ISBN 978-0-8311-3375.

8. M. Weck, C. Brecher, Werkzeugmaschinen 1, Maschinenarten und Anwendungsbereiche,

Springer, 2005, ISBN 10 3-540-22504-8.

9. M. Weck, C. Brecher, Werkzeugmaschinen 2, Konstruktion und Berechnung, Springer 2006, ISBN 10 3-540-22502-1.

10. R. Neugebauer (Hrsg.), Parallelkinematische Maschinen Entwurf, Konstruktion,

Anwendung, Springer, 2006, ISBN 10 3-540-20991-3.

11. LPI-1: Three work places with manually controlled machine tools.

12. LPI-2: Three work places with numerically controlled machine tools.

13. LMS-1: The system for circular interpolation test.

14. LMS-2: The system for laboratory testing of machine tools accuracy.

15. LRS-1: One developmental work place with machine tool of the MOMA type.

16. LRS-2: One work place for testing machine tools mechanisms.

17. LPS-1: Work places for programming machine tool of the MOMA type.

18. APS-1: The system for experimental data acquisition and processing.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 3
laboratory exercises: 17
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 7
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 35
laboratory exercises: 15
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
F. Kimura, K. Horio (Eds.), Towards Synthesis of Micro-/Nano-systems, Springer, 2006, ISBN13: 9781846285585.
M. Mitsuishi, K. Ueda, F. Kimura (Eds.), Manufacturing Systems and Technologies for the New Frontier, Springer, 2008, ISBN 978-1-84800-266-1.
M. Weck, C. Brecher, Werkzeugmaschinen 3, Mechatronische Systeme, Vorschubantriebe, Prozessdiagnose, Springer, 2006, ISBN 10 3-540-22506-4.
M. Weck, C. Brecher, Werkzeugmaschinen 4, Automatisierung von Maschinen und Anlagen, Springer, 2006, ISBN 10 3-540-22507-2.
M. Weck, C. Brecher, Werkzeugmaschinen 5, Messtechnische Untersuchung und Beurteilung, dynamische Stabilität, Springer, 2006, ISBN 10 3-540-22505-6.

Manufacturing Automation

ID: MSc-0785
responsible/holder professor: Jakovljević B. Živana
teaching professor/s: Jakovljević B. Živana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: production engineering

goals
The objective of this course is that students: acquire knowledge of the application, design and implementation of contemporary manufacturing automation; master the skills of practical problem-solving in the domain of automation by using computer, information, control, manufacturing, and other technologies and appropriate scientific methods.

learning outcomes
After successfully completing this course, the students should be capable to:

- Analyze social, economic, production and other effects of automation;
- Integrate knowledge in related subjects and implement them in automation;
- Analyze and synthesize combinational automata;
- Synthesize sequential automata;
- Carry out pneumatic and electro-pneumatic realization of combinational and sequential automata;
- Program programmable logic controllers according to IEC 61131-3.

theoretical teaching
1. Introduction to manufacturing automation: definition of automation; types of production systems automation; fixed, flexible, programmable and intelligent automation; advantages and disadvantages of automation

2. Number systems: additive number systems; positional number systems (decimal, binary, octal, hexadecimal); conversion of numbers between positional number systems

3. Codes and coding: binary coded decimal; conversion between binary coded decimal and binary number system; Gray code; alphanumerical codes

4. Switching algebra: axioms of Boolean algebra; elementary operations of switching algebra; theorems of switching algebra; logic functions; canonical forms of logic functions (sum of minterms and product of maxterms); minimization of logic functions

5. Technologies and components for realization of control tasks in manufacturing automation: the structure of control system - subsystems for information acquisition, information processing and command execution; pneumatic and electro-pneumatic realization; sensors, actuators, logical and memory elements.

6. Combinational and sequential automata: Definition, models, synthesis and analysis; Pneumatic and electro-pneumatic realization

7. Programmable controllers: functions, hardware, software, input-output modules; programming languages and programming according to IEC 61131-3.

8. Examples of manufacturing automation

practical teaching
1. Auditory exercises: examples in automation design, with control system analysis and synthesis, programmable controllers programming, and control scheme design.

2. Laboratory exercises:

PL1 Control of pneumatic actuators

PL2 Analysis of combinational automaton (pneumatic realization)

PL3 Synthesis of combinational automaton (pneumatic realization)

PL4 Synthesis of combinational automaton (electro-pneumatic realization using PLC)

PL5 Synthesis of sequential automaton (electro-pneumatic realization using PLC)

PL6 Synthesis of sequential automaton (electro-pneumatic realization using PLC- timers and counters)

PL7 Synthesis of sequential automaton (electro-pneumatic realization using PLC and programming in sequential function charts)

3. Seminar work: examples of automation design with control system synthesis, programmable controllers programming and control scheme design.

prerequisite
none

learning resources
1. Pilipović M., Jakovljevic, Z, Manufacturing automation, FME, Belgrade, 2017 /In Serbian/

2. Pilipović M., Manufacting processes automation: Laboratory. FME, Belgrade, /In Serbian/

3. Jakovljevic, Z., Manufacturing automation, lecture handouts

4. Laboratory desk with electro-pneumatic components and programmable controllers, Laboratory for manufacturing automation.

5. Pick and place modular robots, Laboratory for manufacturing automation.

6. Programming computers, Laboratory for manufacturing automation.

7. Software for programmable controller programming, Laboratory for manufacturing automation

8. Network of computers and PLCs, Laboratory for manufacturing automation

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 14
calculation tasks: 0
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 20
laboratory exercises: 10
calculation tasks: 0
seminar works: 15
project design: 0
final exam: 50
requirements to take the exam (number of points): 30

references
Groover, M., P., Automation, Production Systems, and Computer Integrated Manufacturing, ISBN: 0132393212, Prentice Hall, 2007
Holdsworth, B., Woods, C., Digital Logic Design, ISBN: 9780750645829, Newnes, 2002
Tinder R., F., Engineering Digital Design, ISBN: 0126912955, Academic Press, 2000
John, K. H., Tiegelkamp, M., IEC 61131-3: Programming Industrial Automation Systems, ISBN: 3-540-67752-6, Springer-Verlag, 2001
Lazic, B. Z., Computer technology basics, ISBN: 86-7466-234-X, Akademska misao, Belgrade, 2006 (in Serbian)

Manufacturing Systems Design

ID: MSc-0177
responsible/holder professor: Petrović B. Petar
teaching professor/s: Petrović B. Petar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
1. Understanding of modern manufacturing systems structure – a survey of main subsystems and their mutual interaction;

2. Static and dynamic properties of the manufacturing system, dynamic nature of cutting process, nonlinear phenomena of friction, chatter and other aspects affecting manufacturing system stability;

3. Fundamental knowledge of numerically controlled axes, Computer Numerical Control, control system architecture, human-machine interfacing, and manufacturing system condition monitoring;

4. Fundamental approaches to manufacturing systems design theory (Axiomatic design, TRIZ and other alternative approaches).

learning outcomes
1. The student should be able to design, i.e., conceptualize, analyze and synthesize manufacturing system in accordance to given functional requirements.

2. The student should develop knowledge, skills and practice for using broad range of CAx modeling methods, including FEM, needed for manufacturing system design and optimization.

3. The student should understand structure of Computer Numerical Control system, its basic architecture and subsystems, and how to specify and/or configure it properly.

theoretical teaching
Theoretical teaching embraces three basic teaching units:

1. Structure and configuration of the manufacturing system – generic structure of the manufacturing system; morphology, static and dynamic aspects of the machine-tool-workpiece interaction, basics of modal analysis; cutting process dynamics, and stability aspects.

2. Control system – basics of numerically controlled machine tool: servo axis, fundamental principles of servoregulation; interpolation and motion control, architecture and configuration of CNC control systems;

3. Manufacturing systems design – introduction to the theory of axiomatic design, design axioms and corollaries; functional requirements and constraints, design matrix and forms of coupling, complexity - structuring and decomposing designs, domain of technology and processes; Theory of Inventive Problem Solving (TRIZ).

practical teaching
Laboratory exercises are organized within the framework of three exercises: 1. manufacturing system statics, 2. manufacturing system dynamics and modal analysis techniques, and 3. control system NUMA (servo axis, engagement of servo axes and contour control, configuring a manufacturing system). Project: project of an assigned manufacturing system or any of its subsystems, focus being on multidisciplinary (mechatronics) approach in solving the problem posed. Students are oriented to using the Internet, contemporary CAD techniques in the design process, team work and practical verification in the laboratory.

prerequisite
Basic knowledge in Mechanics, Machine Tools, Tools, Jigs and Fixtures, Numerical methods and CAD, Electronics, Control Systems, Cybernetics.

learning resources
[1] P.B. Petrovich, Manufacturing systems design /In Serbian/,

[2] Designer Atlas of Machine Tools,

[3] Handouts in e-form /In Serbian/,

[4] Instructions for laboratory report writing /In Serbian/,

[5] Instructions and prominent example of the Manufacturing System Design project /In Serbian/.

[6] Manufacturing systems in Machine workshop of the Department for Production Engineering: 1)Conventional machines - lathes, milling machines and grinding machines, 2) Numerically controlled machines - CNC Lathe and Horizontal machining center with 4 dof.,

[7] Sensory and digital acquisition system for modal analysis of manufacturing systems,

[8] Components of numerically controlled servo axes,

[9] Open architecture CNC control system for motion control of servo driven axes in modern machine tools,

[10] CAD development tools for identification and simulation of static and dynamical behavior of manufacturing systems.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 6
calculation tasks: 0
seminar works: 0
project design: 16
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 10
calculation tasks: 0

seminar works: 0
project design: 15
final exam: 40
requirements to take the exam (number of points): 30

references

Vladimir R. Milacic, Machine Tools II, Faculty of Mechanical Engineering, Belgrade.
Suk-Hwan Suh, at all, Theory and Design of CNC Systems, 2008 Springer-Verlag London Limited, ISBN 978-1-84800-335-4

Mechatronics systems

ID: MSc-0342
responsible/holder professor: Petrović B. Petar
teaching professor/s: Petrović B. Petar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The aim of the course in mechatronics systems is to provide a focused interdisciplinary theoretical knowledge and practical experience for undergraduate students that encompass fundamental elements from traditional courses in mechanical engineering, production engineering, electronics and computer control engineering. These elements include sensors and measurement theory, digital systems and computation, semiconductor electronics, servoactuators and motion control, machine tools and robotics, altogether focused in deeper understanding of mechatronics aspects of modern manufacturing systems design, i.e., design of CNC machine tools, industrial robots and flexible production lines, based on contemporary numerical and computer control technology.

learning outcomes
1. Theoretical and practical knowledge how to design and select analog and digital circuits, microprocessor-based components, mechanical devices, sensors and actuators, so that the manufacturing equipment, i.e., machine tools, manipulating robots and manufacturing lines achieve desired function.

2. Deep understanding of basic principles of computer based numerical control systems and their application in machine tools, manipulating robots and industrial automation systems design.

3. Microcontroller programming and hardware design skills.

theoretical teaching
Theoretical teaching is organized in four teaching units:

1. Importance and role of mechatronics in modern manufacturing systems design,

2. Digital systems, microprocessors and microcontrollers – basic digital modules, arithmetic logic unit, microprocessor, machine and assembly language, microcontroller architecture and programming,

3. Sensory systems, signal conditioning, measurements and signal processing – working principles and design of sensors for force, displacement and speed measurement, signal conditioning based on semiconductor electronics, fundamentals of digital signal processing, vision sensors and systems, and

4. Electrical servo drives and motion control – stepper and dc motor fundamentals, servo drivers and numerically controlled servo axis, motion control and interpolation, CNC system architecture .

practical teaching
Practical training is organized through laboratory exercises and project of mechatronics system design in the field of manufacturing technoloogy.

LAB 1: Microcontroller – demonstration of development system based on Microchip PIC16F87 microcontroller, hardware architecture, microcontroller programming in assembler language, application development using high-level programming languages (MicroPascal, MicroC), working with digital and analogue signals, digital interfaces and microcontroller networking;

LAB 2: Intelligent sensor systems in manufacturing – architecture of intelligent sensor system, design and operation of multi DOF force sensor based on strain gauge transducers, design and operation of laser triangulation sensor for highly accurate contactless displacement measurement, vision sensors and image analysis;

LAB 3: Servo drives and motion control – brushless dc servomotor, servo driver architecture and technical details, servo axis configuration and tuning, contour motion control - synchronization of two servo axes and demonstration of various kinds of interpolation algorithms, performances evaluation, demonstration of CNC system architecture and its building blocks.

Project: mechatronic system design using microcontrollers, microprocessor based sensory signal conditioning and processing, and servocontrolled actuators. The project is focused on specific problem closely related to real industrial scenarios.

prerequisite
Fundamental knowledge on Dynamics of mechanical systems, Electrical Engineering, Control Systems Eng., Cybernetics, and Computer programming skills

learning resources
[1] P.B.Petrović, Mechatronics systems in mechanical engineering (Textbook in preparation) /In Serbian/;

[2] Handouts for each lecture. /In Serbian/;

[3] Instructions for writing laboratory reports/In Serbian/,

[4] Instructions and a referent example of the project /In Serbian/,

[5] Instructions for safe handling of laboratory equipment /In Serbian/.

[6] MatLab simulation system practical training in dynamic systems simulation and analyis,

[7] Development system based on Microchip PIC16 and PIC18 RISC microcontrollers for practical understanding digital computer organization and machine language,

[8] Compilers and High-level language development systems for Microchip PIC16 and PIC18 RISC microcontrollers (MicroC, MicroPascal),

[9] Peripheral modules for Microchip PIC16 and PIC18 RISC microcontrollers for practical trainings with digital and analogue signals, interfacing and networking and building human-machine interfaces,

[10] Force sensing demonstration and training installation (multy dof. strain gauge based senors, signal conditioning and digital signal acquisition system),

[11] Noncontact displacement measuring 3d scanning system based on laser triangulation and structured light concepts; demonstration and training installation (sensory sistems, signal conditioning and digital signal acquisition system, digital signal processing and information extraction),

[12] Servo-axis demonstration and training test bead (servomotors, mechanical drive components, displacement measuring sensors (encoders), guiding system),

[13] Open architecture control system for motion control demonstration of servodriven systems, HMI and control code development system from CAD data

[14] Robot arms and mobile robot for students training in practical use of microcontrollers for different tasks in motion control of complex mechanical systems.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 6
calculation tasks: 0
seminar works: 0
project design: 16
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 6
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 25
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 15
final exam: 40
requirements to take the exam (number of points): 30

references
W. Bolton, Mechatronics – Electronic control systems in mechanical and electrical engineering, Prentice Hall, 2003.
D. Alciatore, and M. Histand, Introduction to Mechatronics and Measurement Systems, McGraw-Hill Company, 2003.
Suk-Hwan Suh, at all, Theory and Design of CNC Systems, 2008 Springer-Verlag London Limited, ISBN 978-1-84800-335-4
Robert H. Bishop, MECHATRONICS - AN INTRODUCTION. Published in 2006 by CRC Press, Taylor & Francis Group, ISBN 0-8493-6358-6.

Micro Manufacturing and Characterization

ID: MSc-0601
responsible/holder professor: Bojović A. Božica
teaching professor/s: Bojović A. Božica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The course's goals are: students should achieve a basic knowledge of micro-machining technologies through study manufacturing and measuring systems and their functions in the micro scale, as well as the necessary knowledge for the manufacturing and characterization of parts of contemporary materials; students should study in details the chosen method; students will be trained to write term paper, elaborate on lessons learned and be able to continue practicing this discipline in the profession either further education or research in this area.

learning outcomes
At the end of this course students will be able to:

Apply basic principles of manufacturing in the micron area

Identify the different machine and tools, industrial robots, assembly and transport systems and automation systems applicable to micro manufacturing

Select the suitable methods of micro manufacturing according to techno-economic criteria.

Select the principle of measurement and characterization of functional primitives

Understanding the properties of the material adequate for micro manufacturing.

Apply scientific methods of analysis, synthesis and design, as well as computer technology

theoretical teaching
AT-1: Introduction to micro technology and an overview of previous situation in that area; AT-2: Methods for micro-cutting process, AT-3: Methods of processing micro-plastic deformation; AT-4: Methods of processing micro-pressure casting polymer; AT-5 : Methods of processing micro electro erosive processing; AT-6: Micro Metrology, AT-7: Fundamentals microtribology and its role in micro technologies, AT-8: Characterization of engineering surfaces, AT-9: Application of laser in microtechnology, AT-10: Microlithography.

practical teaching
PA-1, PA-2 PA-3 PA-4 PA-5 PA-6: Examples of implemented solutions regarding the teaching topics, PZ-1: The task in the field of micro-processing, PZ-2: The task in the field of micro- metrology; PZ-3: The task in the field of characterization; PL-1, PL-2: Laboratory practice in the field of micro-cutting, PL-3: Laboratory practice in the field of micro-measurements, PK-1, PK-2: Consultation regarding the term paper , PS-1: Term paper title choosing and definition of the paper, PS-2: Searching the available literature; PS-3: Searching the Internet resources, PS-4: Analysis of collected information ; PS-5 PS-6 PS-7, PS- 8: Independent work on term paper , PS-9: Final work on the preparation of term paper, PS-10: Finalisation of the paper by making and preparing presentations;

prerequisite
Defined by the Study Program Curriculum

learning resources
Handouts - writing material in the form of pdf and ppt files from the lecture.

The scanning microscope JSPM-5200 and software for image processing WinSPM Ver.2.5, CNC lathe Politech Aspheric 1800 - Toric,

milling machine - Roland CAMM PNC2300-2.

number of hours: 75

active teaching (theoretical): 20
lectures: 20
elaboration and examples (revision): 0

active teaching (practical): 40
auditory exercises: 12
laboratory exercises: 6
calculation tasks: 6
seminar works: 14
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 1
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 20
laboratory exercises: 10
calculation tasks: 10
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Ehman, K., Bourell, D., Culpepper, M., at al. MICROMANUFACTURING, Springer, Netherlands, 2007.
Lasagni, F., Lasagni, A., FABRICATION AND CHARACTERIZATION IN THE MICRO-NANO RANGE, Springer, Berlin, 2011.
Franssila, S. INTRODUCTION TO MICRO FABRICATION, John Wiley & Sons, Ltd. England, 2004.
Saleem Hashmi, COMPREHENSIVE MATERIALS PROCESSING, Elsevier, 2014
Mahalik, N.P. MICROMANUFACTURING AND NANOTECHNOLOGY, Springer, Germany, 2006

New generation of machine tools and robots

ID: MSc-1107
responsible/holder professor: Živanović T. Saša
teaching professor/s: Živanović T. Saša, Slavković R. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
1. Perception of different levels of the new generation of machine tools and robots concept.

2. Acquisition of basics of reconfigurable, high-speed, meso- and micro-machines and highaccuracy machine tools.

3. Practical knowledge about parallel kinematic machines and machines for material addition processes and multi-axis machining.

4. Development of programming skills relevant for the new generation of machine tools and robots.

5. Development of report-making skills.

learning outcomes
After completed this course the students should be able to:

•Understand the role, importance, types and applications of the new generation of machine tools and robots.

•Understand different levels of the new generation of machine tools and robots concept.

•Select appropriate new generation machine tools and robots for given technological task.

•Select and prepare environment for operation of machine tools and robots.

•Programming the new generation of machine tools and robots.

•Use new programming methods for numerically controlled systems.

theoretical teaching
New teaching contents:

T1. Definition and classification of the new generation of machine tools and robots.

T2. Reconfigurable machine tools.

T3. High-speed machine tools.

T4. Machines for material addition processes.

T5. Parallel kinematic machines concepts.

T6. Identification of geometry and kinematics in parallel kinematic machines.

T7. Multi-axis machine tools.

T8. Multi-axis machining robots.

T9. Meso- and micro-machines.

T10. High-accuracy machine tools.

Extension:

(a) Extension of T1 and calculation tasks relevant for parallel kinematic machines geometry.

(b) Extension of T2 and calculation tasks relevant for parallel kinematic machines.

(c) Extension of T3 using the examples of meso- and micro-machines.

(d) Extension of T4 using the examples of machine tool calibration.

(e) Extension of T5 using the examples of compensations in the machining system.

practical teaching

Practical teaching involves auditorial exercises, laboratory work and seminar work writing.

1. Auditorial exercises: (1)Resources for studying the new generation of machine tools and robots. (2)Analysis of reconfigurable machines. (3)Machine tool calibration and compensations in the machining system.

2. Laboratory exercises: (1)Programming of machines for material addition processes.

(2)Programming of DELTA robot. (3)Programming of parallel kinematic machines. (4)Programming of multi-axis machining. Instructions are provided for each exercise and the necessary work sheets.

3. A seminar work on the new generation of machine tools and robots.

4. A report is written on the knowledge acquired during the course according to instructions and model provided at the start of the course. A part of the report is a seminar work.

prerequisite

Study curriculum and student motivation for learning about machine tools and industrial robots according to the goals set and outcomes offered.

learning resources

1. Documents on the web site http://cent.mas.bg.ac.rs/nastava/ma_bsc/indexnma.htm.

2.Documents for the areas of parallel mechanisms and multi-axis machining of robots.

3. W. R. Moore, Foundations of Mechanical Accuracy, The Moore Special Tool Company, First Edition, Third Printing, 1999.

4. Y. Ito, Modular Design for Machine Tools, McGraw-Hill, 2008, DOI: 10.1036/0071496602.

5. D. Kochan, Ed, Solid Freeform Manufacturing, Advanced Rapid Prototyping, Elsevier, 1993, ISBN 0-444-89652-X.

6. H. Schulz, Hochgeschwindigkeitsfraesen metallischer und nichtmetallischer Werkstoffe, Hanser Verlag, 1989, ISBN 3-446-15589-9.

7. K. Ehmann, D. Bourell, M. Culpepper, T. Hodgson, T. Kurfess, M. Madou, K. Rajurkar, R. DeVor, International Assessment of Research and Development in Micromanufacturing, Final Report, WTEC, 2005.

8. Tsai L.-W. (1999) Robot Analysis: The Mechanics of Serial and Parallel Manipulators, Wiley, New York.

9. Merlet J.-P. (2000) Parallel Robots, Kluwer Academic Publisher, Dordrecht, The Netherlands.

10. PRA-1: Practicum in preparation.

11. LPI-1: Two work-places equipped with prototypes of the new generation of machine tools (3-axis parallel milling machine, desktop 3-axis parallel milling machine).

12. LPI-2: Two work-places equipped with prototypes of the new generation of robots (serial machining robot, DELTA robot).

13. LPS-1: Functional simulators of parallel kinematic machines.

14. LPS-2: Functional simulator of the machine for prototype building.

15. CSP-1: Two work-places equipped with the software for programming of multi-axis machining.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 21
calculation tasks: 0
seminar works: 4
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 1
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 50
laboratory exercises: 10
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
J. A. McDonald, C. J. Ryall, D. I. Wimpenny (Eds.), Rapid Prototyping Casebook, Wiley, 2001, ISBN: 978-1-86058-076-5.
R. I. Noorani, Rapid Prototyping: Principles and Applications, Wiley, 2005, ISBN 13: 978-0-471-73001-9.
S. S. Makhanov, W. Anotaipaiboon, Advanced Numerical Methods to Optimize Cutting Operations of Five-Axis Milling Machines, Springer, 2007, ISBN 978-3-540-71120-9.
L. C. Hale, Principles and Techniques for Designing Precision Machines, Ph.D. Thesis, 1999, Lawrence Livermore National Laboratory, UCRL-LR-133066.
N. Taniguchi, T. K, K. M, K. I, I. M, T. D. (Eds.), Nanotechnology, Integrated Processing Systems for Ultra-precision and Ultra-fine products, Oxfod University Press, 1996, ISBN10: 0198562837.

New Technologies

ID: MSc-0104
responsible/holder professor: Puzović M. Radovan
teaching professor/s: Popović D. Mihajlo, Puzović M. Radovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The aims of introducing new technologies to production are top quality products, low-cost and short-time manufacturing process. This course is intended for students of the Production Engineering Department. Students are familiarized with modern technologies that make possible to extend knowledge acquired in Manufacturing Technology and Production Technologies and Metrology.

learning outcomes
On successful completion of the course, students should be able to:

•Design technology for building complex machine parts from various materials (metal, metal powder, polymer, ceramic, stone, etc.).

•Design technology for manufacturing of cutting tools (powder metallurgy).

•Identify versatile specificities of plastic parts pressure casting tools, stamping

tools for metal parts.

•Use some of the advanced software tools for simulations of the polymer material

parts pressure casting process, along with analysis and presentation of

experimentally obtained results.

•Draft a plastic parts pressure casting tool for a specified part.

•Apply some of the developed CAD/CAE/CAM software tools for modeling drafted

polymer material parts pressure casting tools.

theoretical teaching
AN-1: Introduction to new technologies; AN-2: Contemporary tools and tool materials; AN-3: Technology of synthesis; AN-4: Finish cutting technologies; AN-5: Machining technology by abrasive suspension; AN-6: Technology of powder metallurgy; AN-7: Technology of polymer shaping; AN-8: Forging technology; AR-1: Consolidation of teaching contents through presentation of new technologies; AR-2: Survey of contemporary cutting tools and tool materials application; AR-3: Demonstration of technology of synthesis; AR-4: Consolidation of teaching contents related to finish cutting methods; AR-5: Giving instructions for the design of tools for building machine parts from plastic masses; AR-6: Giving instructions for forging tools design;

practical teaching
PP-1: Design of tools for building machine parts from plastic masses or forging tools design (students opt for the design of one of the offered tools); PL-1: Standard and special cutting tools (tool material, geometrical shapes of tools, tool assembly, and tool use); PL-2: Application of machining technology by abrasive suspension (demonstration on concrete examples); PL-3: Tools for building machine parts from plastic masses (components, molding systems, assembly, exploitation characteristics; PL-4: Forging tools (components, casting systems, assembly, exploitation characteristics).

prerequisite
Defined by the Study Program Curriculum

learning resources
1. Handouts (PDF files) (18.) /In Serbian/
2. Kalajdžić M., Manufacturing technology, FME, Belgrade, 2005 (18.2) /In Serbian/
3. Laboratory equipment (tools and machines) at IMT (18.12)
4. SAx software work station (CAD, CAM, CAE, CAPP,...), (CAX) (18.13)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 12
calculation tasks: 0
seminar works: 0
project design: 18
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 15
final exam: 30
requirements to take the exam (number of points): 40

references
Handouts (PDF files) (18.) /In Serbian/
Kalajdžić M., Manufacturing technology, FME, Belgrade, 2005 (18.2) /In Serbian/
Laboratory equipment (tools and machines) at IMT (18.12)
SAx software work station (CAD, CAM, CAE, CAPP,...), (CAX) (18.13)

Production information systems

ID: MSc-0786
responsible/holder professor: Puzović M. Radovan
teaching professor/s: Mladenović M. Goran, Puzović M. Radovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
1.Acquisition of nowledge about the role and importance of computer-oriented information systems for planning and management of production systems

2. Mastery of theoretical basics of contemporary information systems architecture

3. Acquisition of practical knowledge for applications design and development in the domain of information systems for planning and management of production systems

learning outcomes
On successful completion of the course, students should be able to:

•Identify basic concepts in the sphere of computer-oriented information systems design and development.

•Identify the application and role of contemporary database management systems.

•Define sub-systems (modules) within the production system, documentation and information flows within the sub-system and their interactions within the overall system.

•Design database logical structure for a corresponding technological sub-system with description of required attributes for each entity and links between the entities.

•Use contemporary software tools in the design and development of production information systems.

theoretical teaching
Information systems for new concepts of production systems. Possible creation of contemporary concepts, such as CIM/CIE, TQM, Kanban system or MRP-II systems, as well as concepts of organizational structures, such as concepts of virtual enterprises, network production, e-production systems based on architectures of the system in the network environment. Processes in the client/server architecture are also the subject-matter of the course. Production system functional structure, its structuring primarily into subsystems of a production technological system: structural information management, technological information management, stock management, current business operations management, tools system management, transport management, maintenance management, all implying information modeling, database modeling, defining the object-link diagrams (EP diagram), DBMS choice, developing physical data model up to the application development level

practical teaching
The student acquires practical knowledge for the design and development of software applications in the domain of production systems planning and management. Using some of the available software tools for creating a database, the student passes through all stages of developing new software application for a concrete subsystem. This means the analysis of defined functions of planning and management, design and detailed elaboration of the designed solution, its practical realization, testing and official presentation in front of the teacher and other students

prerequisite
There are no prerequisites

learning resources

Handouts in e-form /In Serbian/. Instructions for laboratory exercises /In serbian/. Instructions for project design /In Serbian/. One-student-one-computer scheme in a computer room. Software tool for application development (Oracle, MS Access, Progress,...)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 7
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 30
requirements to take the exam (number of points): 40

references

Handouts in e-form (In Serbian).
Milačić V.: 2 Production Systems, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, in 1982. (In Serbian)
Stephen N. Chapman: The Fundamentals of Production Planning and Control.
Jorg Thomas Dickersbach and Gerhard Keller: Production Planning and Control with SAP ERP (2nd Edition)

Quality Management

ID: MSc-1167
responsible/holder professor: Stojadinović M. Slavenko
teaching professor/s: Stojadinović M. Slavenko
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
The objective of this course is to acquire knowledge and skills necessary for solving theoretical and practical problems in the field of quality management of products and services, that are necessary for successful further scientific-professional work of students and engineers. Students should: to master the basic terms, the definition of quality and the development of systematic approaches to improving quality; to get familiar with analytical methods of quality management and quality engineering techniques; acquire knowledge from statistical methods of quality management; acquire skills from experimental methods of quality management; to get familiar with the quality standards, requirements and the implementation of the ISO 9001 series.

learning outcomes
After successfully completion of this course, the students should be capable to: determine and define the scope of quality management in an industrial environment; classify, rank, analyze and evaluate the importance of quality characteristics; calculate the partial and total processing error for a particular technology and processing conditions and analyze the accuracy of the process; design and application of statistical quality engineering techniques for concretely production conditions: get static sheet, control card and acceptance plan; generate a measurement protocol on a measuring machine, execute measurement and analyze the measurement results; interpret, application and document requirements ISO 9OO1 for the organization; prepare and implement a TQM project for the organization.

theoretical teaching
Theoretical teaching embraces ten units: 1. Definition of product quality in the business or technological system. Definition of quality management. Development of systematic approaches to quality improvement. 2. Analytical method of quality management. Analysis and synthesis of machining errors. 3. Errors of machining due to elastic deformation of the machining system. Compensation methods. 4. Errors of machining due to thermal deformation of the machining system. Machining errors due to wear and fabrication errors. Tool regulation errors. 5. Statistical methods of quality management. Method of layout curve analysis. Control charts. 6. Acceptance plan, definition, classification, application. 7. Measuring chains. Measurement and inspection. 8. Planning of measurement and inspection on CMM. 9. ISO 9001 - requirements and applications. ISO 9001 - certification. ISO 9001 for small and medium organizations. 10. Total quality management. Quality Awards.

practical teaching
Practical teaching embraces seven units: six auditory and one laboratory exercises, as well as seminar work in the area of quality standards. The content of auditory exercises is as follows: 1. Linear regression; 2. Analytical method - first part; 3. Analytical method - second part; 3. Testing the hypothesis; 4. Control charts; 5. Acceptance plan; 6. Measuring chains.

The topic of the laboratory exercise is: The example of preparation for inspection on the CMM, simulation and generation of the measurement protocol. Development of six individually computational tasks from engineering analysis and synthesis using the quality engineering techniques. Quality management in practice - discussion and workshop (visit to the selected factory and familiarization with the functioning of ISO 9000 in practice).

prerequisite
Defined by curriculum of study programme.

learning resources
1. Handouts for each lecture. 2.The instruction for making individualy tasks and seminar work. 3. The monograph in the field of quality and production metrology. 4.The web site of the course with addresses of leading organizations and important institutions in this area (under preparation). 5. Facility and technical equipment: Laboratory for production metrology and TQM.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 3
calculation tasks: 5
seminar works: 8
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 1
check and assessment of lab reports: 0
check and assessment of seminar works: 1
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 25
seminar works: 5
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Stojadinovic, S., (2018), Handouts for each lecture.
Stojadinovic, M.S., Majstorovic, D.V. (2019), An Intelligent Inspection Planning System for Prismatic Parts on CMMs, Springer International Publishing, 978-3-030-12806-7.
Stanic, J., Products quality management - methods I, Faculty of Mechanical Engineering, Belgrade
Majstorovic, V., Products quality management I, Faculty of Mechanical Engineering, Belgrade
Stanic, J., Products quality management - methods II, Faculty of Mechanical Engineering, Belgrade

Sheet-Metal Processing Tools

ID: MSc-1362
responsible/holder professor: Pjević D. Miloš
teaching professor/s: Pjević D. Miloš, Popović D. Mihajlo
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: production engineering

goals
Acquisition of theoretical and practical knowledge in the domain of the design, calculations and construction of tools for sheet-metal processing by punching, drilling, bending, drawing, and combination of these methods. The student acquires a sound understanding of the importance of team work and cooperation in the area of the design based on contemporary technologies and optimal solution.

learning outcomes
On successful completion of the course, students should be able to:

• Evaluate each element of the tool for its construction and function with respect to the material and performance.

• Identify different concepts of cutting sheet-metal plates, strips and work-pieces, and perform computations for metal efficiency level, which enables students to also understand economic indicators.

• Identify different concepts and specificities of sheet-metal processing tools.

• Create a concept of a sheet-metal processing tool for a specified part.

theoretical teaching
The mathematical theory of plasticity and physics of plastic deformation in solids (hypotheses and models of solids). Plastic deformation mechanism. Continuum mechanics. Elastic repositioning of sheet metal. Deformation force and work in processing by punching, drilling, bending, drawing. Determination of the sheet-metal holder force. Determination of the press force. Determination of the tool pressure center. Determination of preliminary work-piece measurements for components manufactured by bending and drawing. Determination of the sequence and number of operations. Construction characteristics of tool working elements.

practical teaching
During laboratory exercises the student is acquainted with practical realization of sheet-metal processing tools. Project design for a concrete practice-related work-piece. Tools for making normal-accuracy components. Single-operating, multiple-operating and combined tools. Tools for making ribs for smaller or larger hole shaping. The hole enlargement by edge drawing. A visit to the factory where students are acquainted with the tool making technological process. Acquainting students with recommendations from practice relevant to tool design.

prerequisite
Defined by the Study Program Curriculum

learning resources
1. Standardized tool elements, Sheet-metal processing tool elements, Lab for FTS, machining processes and tools, ЛПС

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 2
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 14
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 0
test, with assessment: 4
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 40
requirements to take the exam (number of points): 30

references

Jovičić M., Tanović Lj., TOOLS AND TOOLING FIXTURES - calculations and constructrions of sheet-metal processing tools, FME, Belgrade, 2007, КПН

Skill Praxis M - PRO

ID: MSc-1195
responsible/holder professor: Slavković R. Nikola
teaching professor/s: Mladenović M. Goran, Slavković R. Nikola
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: production engineering

goals
The student gains practical experience and gets familiarized with the future occupational environment. The student identifies basic functions of the business system in the domain of design, development, and manufacturing as well as the role and tasks of the mechanical engineer within such a business system.

learning outcomes
Upon successful completion of this course students should be able to:

(1) Apply practical experience on the organization and functioning of the business environment in which they will apply the acquired knowledge in their future professional career.

(2) Students can identify the models of communication with the colleagues and business information flow.

(3) Solve basic processes in the design, manufacturing, maintenance within the context of their future competences.

(4) Establish of contacts and acquaintances are useful during graduate studies as well as for applying for the job in the future.

(5) Prepare by Report professional practice upon on the completed tasks in given topics.

theoretical teaching
This professional practice M PRO has no lectures. Students use the knowledge acquired during their studies at the Faculty of Mechanical Engineering.

practical teaching
Practical teaching means work in the companies where various activities related to mechanical engineering are proceeding. The subject matter and business company or research institution is selected in consultation with the professor. In principle, the student is allowed to conduct skill praxis in manufacturing companies, design and consulting firms, enterprises for machine equipment maintenance, public enterprises and municipal service companies or any laboratory at FME. Skill praxis can also be performed abroad. Students are obliged to keep a diary of skill praxis, where they describe the jobs they are doing, write down deductions and perceptions. Having completed the skill praxis the students must make a report they will defend in front of the professor. The report is handed over in the form of a seminar work.

prerequisite
Defined by the Study Program Curriculum.

learning resources
Laboratories of the Department of Production Engineering.

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0

active teaching (practical): 80
auditory exercises: 0
laboratory exercises: 80
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 70
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 50

references

RAILWAY MECHANICAL ENGINEERING

Brakes of rail vehicles

ID: MSc-1189
responsible/holder professor: Milković D. Dragan
teaching professor/s: Milković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: railway mechanical engineering

goals

1. Introducing the brake system of railway vehicles.

2. Acquiring the knowledge necessary to understand the functioning of rail vehicle brake system components.

3. Training for the application of knowledge in the design, development, repair and maintenance of the brakes.

learning outcomes

After completion of the course the student should be able to:

1. Explain the functional and design characteristics of various types of brakes.

2. Explain the tasks and functioning mode of brake system assemblies.

3. Identify actions required to be aplied in case of malfunctions of the break system during operation and maintenance.

4. Apply appropriate regulations and standards for design and maintenance of rail vehicle brakes.

theoretical teaching

The general braking conditions. Friction and friction materials. The main types of brakes and braking techniques. The transfer of the braking action by means of the compressed air. The main braking conditions. Transmission speed, transmission time, braking time and release time. The process of braking. Braking, brake weight, weight at changeover. The stopping distance and stopping time. Braking tables. Adjusting the brake force to the load. Thermal and other restrictions of the braking force. Emergency brake. Handbrake. Electromagnetic rail brakes. UIC regulations relating to the brakes of railway vehicles. Braking modes RIC, R, S, SS ... The calculation of the brakes for passenger and freight cars. Formation and tansmission of the braking force: compressor with accessories, the main pipe, tanks, distributor, brake cylinder, mechanical transmission, slack adjuster. Executive parts: brake holders, brake shoes, discs, calipers, brake pads, other accessories. Testing of brakes: type and serial tests of the brakes and brake equipment. Experimental determination of the braking power.

practical teaching

Clasification of the brakes. Functional scheme of basic types of brakes. Functional scheme of pneumatic brakes. The working principle of control valve. The working principle of the distributor valve. Brake system schemes for typical rail vehicles. Gear ratio and the coefficient of efficiency. The design of the brake with brake shoes. Braking parameters selection based on regulations. The design of disc brakes. Visit the workshop for the brake maintenance. Braking tables. Examples of calculation. Examples of braking mass determination based on the brake stopping distance tests. Calculation of brake mass. Calculation of the handbrake. The design of the braking force transmission elements. The design of magnetic rail brakes, parking brake, emergency brake. Brakes for high-speed trains.

prerequisite

It is recommended previously to pass course Railway vehicles 1.

learning resources

Milovanović, M., Lišanin, R., Brakes and braking of rail vehicles (in Serbian),Faculty of Mechanical Engineering, Belgrade 2000

Milovanović, M., Lišanin, R., Vukšić-Popović, M., Kržić, Đ., Brakes and braking of rail vehicles- basis for design, selection and and maintenance (in Serbian),Faculty of Mechanical Engineering, Belgrade 2007

For tasks realization shall be used the appropriate regulations and standards.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 2
calculation tasks: 7
seminar works: 0
project design: 0
consultations: 3
discussion and workshop: 4
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 20
laboratory exercises: 10
calculation tasks: 30
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Fundamentals of Rail Vehicle Dynamics

ID: MSc-1190
responsible/holder professor: Milković D. Dragan
teaching professor/s: Milković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals

1. Acquiring knowledge about the dynamic behavior of rail vehicles.

2. Exploring methods for studying the dynamic behavior of rail vehicles.

3. Training for the application of knowledge in the design, development, repair and maintenance of railway vehicles.

learning outcomes

After completion of the course the student should be able to:

1. Explain the characteristic phenomena of dynamic behaviour of rail vehicles.

2. Apply computational methods for determining the main parameters of the dynamic behaviour of the rail vehicles.

3. Participate in the preparation of the test procedures for tests of the dynamic behaviour and proper assesement of the test results.

4. Apply appropriate regulations for design or refurbishment of rolling stock in order to achieve the prescribed dynamic behaviour.

theoretical teaching

Modeling of the dynamic behaviour of the rail vehicles. Geometrical deviations of the track and deviations of wheelset geometry as the excitation source. An elementary model of the vertical oscillation of vehicles with single-stage suspension. The appearance of resonances during movement along track with vertical harmonic deformations. The influence of damping. The behavior of vehicles with dry damping elements. Model of the railway vehicle with two-stage suspension in vertical direction. Application of matrix calculus in solving the dynamic problems. Fundamentals of rail vehicle lateral dynamics. A hunting movement of the wheelset-Klingel solution. The contact geometry. Equivalent conicity. The forces in the wheel-rail contact. The movement of bounded wheelset. Stability of motion. Critical speed. Modelling of stationary, quasi-static motion of the bogie in the curve using the center of friction method. Criteria for assessing the behavior of rail vehicles in motion. (Y/Q) criterion. Criterion of the H forces. Sperling Ride Index. Tests according to UIC 518. Criteria ISO/ORE (UIC518).

practical teaching

Examples of excitation: denivelation of the rails, out off roundness and eccentricity of the wheel, track deformations, harmonic deformations. Excitation simulation. Linear and nonlinear characteristics of elastic and damping elements. Linearization of the characteristics. Examples of one degree of freedom models. Typical dry friction elements used on rail vehicles. The model with dry friction. Example of two axle bogie model in the vertical plane. Effect of selection of generalized coordinates to equation coupling. Example of the freight wagon model with bogies. Example of model of passenger coach two-stage suspension in the vertical plane. Solving problems with more degrees of freedom using computer software. Review of tests of passenger coach dynamic behaviour.

prerequisite
Previously passed courses in Mechanics of rigid bodies and at least 18 EPSB, with at least one course of Dynamics.

learning resources
D. Milković, Fundamentals of rail vehicle dynamics, hand-out.

User guides for appropriate software.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 11
seminar works: 0
project design: 0
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 6
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 30
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Locomotive 1

ID: MSc-0243
responsible/holder professor: Lučanin J. Vojkan
teaching professor/s: Lučanin J. Vojkan, Tanasković D. Jovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals
1. Introduction student to the basic concepts important for understanding the designing of diesel locomotives.

2. Knowledge acquiring necessary for understanding the designing of diesel locomotives.

3. Competence for use the knowledge acquired in solving practical problems in designing, use and maintenance of diesel locomotives.

learning outcomes
After successfully finishing of course students would be able to:

- define basic characteristics of diesel locomotives;

- describe tasks and way of functioning of assemblies of diesel locomotive;

- compare tractive characteristics of different types of power transmissions;

- calculate the key parameters using special software package;

- implementation of regulations and standards in field of diesel locomotives.

theoretical teaching
Brief history, Overview of historical development and traction vehicles basic characteristics, High speed vehicles, Influential factors on adhesion, Traction force, Resistance during motion, Basic conception of diesel traction vehicles, Introductions with the basic framework, Design of the running bogie and the supporting vehicle structure, Diesel motor - specification of diesel motors for railway vehicles, Power supply characteristics, Modern motors for railway vehicles, Examination and emission of exhaust gases, Characteristics of units for power transmission on railway vehicles, Design of mechanical transmitters, Design of hydrodynamic transmitters, Joint operation of diesel motor and hydrodynamic transmitter, Design of cooling systems.

practical teaching
Practical training, Auditory exercises (Introductions with examples regarding learned materials - Modern solutions of diesel motors for railway vehicles, Mechanical transmitters for railway vehicles, Hydraulic - hydrostatic and hydrodynamic transmitters for railway vehicles, Regulation of diesel motor and transmitter joint operation, Accessories on diesel locomotives), Solving the set problem (Designing of diesel hydraulic locomotives power supply systems), Introductions with practical problems in the field of inspection and maintenance of diesel locomotives, Visiting the factory for production of diesel locomotives, Discussion and workshops.

prerequisite
Nothing

learning resources
Syllabus, Guidebook for solving the tasks, Handouts, Personal PC, Projector and internet access - internet exploring for additional information's.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 10
seminar works: 15
project design: 0
final exam: 35
requirements to take the exam (number of points): 35

references
Karl Sachs, Elektrishe Triebfahrzeuge, Springer-Verlag, Wien New York, 1973
Zdravko Valter, Diesel - electric locomotives, Školska knjiga, Zagreb, 1985

Locomotive 2

ID: MSc-0230
responsible/holder professor: Lučanin J. Vojkan
teaching professor/s: Lučanin J. Vojkan, Tanasković D. Jovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals
1. Introduction student to the basic concepts important to understanding the the designing of diesel-electric and electric locomotives.

2. Knowledge acquiring necessary for understanding the designing of diesel-electric and electric locomotives.

3. Competence for use the knowledge acquired in solving practical problems in designing, use and maintenance of diesel-electric and electric locomotives.

learning outcomes
After successfully finishing of course students would be able to:

- define basic characteristics of diesel-electric and electric locomotives;

- describe tasks and way of functioning of the main assemblies of diesel-electric and electric locomotives;

- compare ways of functioning and control of electric drive motors for DC and AC power;

- calculate the key tractive parameters using special software package;

- implementation of regulations and standards in field of diesel-electric and electric locomotives.

theoretical teaching
Brief history, Overview of historical development and basic characteristic traction vehicles, High speed vehicles, Influential factors on adhesion, Traction force, Resistance during motion, Basic conception of diesel traction vehicles, Introductions with basic frame, Design of the bogie and the frame, Diesel motor - specification of diesel motors for railway vehicles, Power supply characteristics, Modern motors for railway vehicles, Examination and emission of exhaust gases, Characteristics of units for power transmission on railway vehicles, Design of mechanical gear, Design of hydrodynamic gear, Diesel motor and hydrodynamic gear working together, Design of cooling systems.

practical teaching
Practical training, Auditory exercises (Introductions with examples regarding learned materials - Modern solutions in the field of electric machines , Generators and Traction motors, Adjustments technique), Solving the set problem (Designing of diesel locomotives power supply systems), Introductions with practical problems in the field of inspection and maintenance of electric locomotives, Practical examples in the field of the electrical vehicles speed regulation - thyristors regulation, transducer. Visiting the maintenance shop for the electric locomotive. Exploring the traction vehicles components. Discussion and workshops.

prerequisite
Attended the course Locomotive 1.

learning resources
Syllabus, Guidebook for solving the tasks, Handouts, Personal PC, Projector and internet access - internet exploring for additional information's.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 10
seminar works: 15
project design: 0
final exam: 35
requirements to take the exam (number of points): 35

references
Karl Sachs, Elektrishe Triebfahrzeuge, Springer-Verlag, Wien New York, 1973
Zdravko Valter, Diesel - electric locomotive, Školska knjiga, Zagreb, 1985

Rail vehicles 1

ID: MSc-1186
responsible/holder professor: Milković D. Dragan
teaching professor/s: Milković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals

1. Understanding of different constructions of the freight wagons and passenger coaches
2. Acquiring the knowledge necessary to understand the functioning of wagon or coach assemblies
3. Application of knowledge in the design, development, repair and maintenance of wagons and coaches

learning outcomes

After completion of the course the student should be able to:

1. Explain the functional and structural characteristics of various types of rolling stock.
2. Explain the tasks and functioning principles of the assemblies of the rail vehicles.
3. Identify actions required to resolve failures in operation and maintenance of rail vehicles.
4. Apply appropriate regulations and standards for design and maintenance of railway vehicles.
5. Applicate computer tools for calculating and designing rail vehicles.

theoretical teaching

General fundaments for designing rail vehicles. Main assemblies of the rail vehicles. The structural parameters of the vehicle. Standards and regulations in the design, operation and maintenance of rail vehicles. Wheelsets. Axle bearings. Single axis running gear. Typical bogies for wagons. Bogies for passenger coaches. Bogie breakaway torque. Running gear with independent wheels. Calculation of the rail vehicles gauge. Flexibility coefficient. Checking the relative position between the running gear and the carbody. General overview of the loads acting on the structure of the wagon. Unbalanced lateral acceleration. Calculation of the rail vehicle rollover safety. Calculation loads for axle strength check.

Design of the carbody bearing structure. Materials for the bearing structure. Regulations for design loads and allowable stresses for carbody and for bogie frame. Strength calculation. Strength test. Passive safety measures for the crash scenario.

practical teaching

Division of rail vehicles. Selection of basic parameters and their constraints. The examples and analysis of excerpts from the regulations. Characteristic wheel profile measurements. Pressed-on or shrunk-on fitting of wheelsets and shrunk-on fitting of the wheel tyres on the wheel centers. Examples of axle bearing assemblies. Design of typical freight wagon bogies. Design of passenger coach bogies. Vehicle gauge calculation. Calculation of relative position between running gear and the carbody. Determination of the general vehicle loads.

Calculation of the carbody bearing structure. Checking the stability of the bearing elements of the structure.

Fundamentals of stress measuring techniques. Procedure for strength testing of the carbody.

prerequisite

Previously finished equivalent of at least: 12 ECTS in Mechanics of rigid bodies, 6 ECTS in Mechanic of deformable bodies and 6 ECTS Machine elements.

learning resources
G. Simic, Rail vehicles- Constructions and calculations, Faculty of Mechanical Engineering 2013.

G. Simic, Instructions for writing student papers, hand-out

For preparation tasks as a basis should be used the appropriate regulations and standards

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 11
laboratory exercises: 0
calculation tasks: 0
seminar works: 3
project design: 8
consultations: 3
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 1
check and assessment of projects: 5
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 30
final exam: 35
requirements to take the exam (number of points): 40

references
G. Simic, Rail vehicles- Constructions and calculations, Faculty of Mechanical Engineering 2013.

Rail vehicles 2

ID: MSc-1188
responsible/holder professor: Milković D. Dragan
teaching professor/s: Milković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals
1. Understanding different constructions of the freight wagons and passenger coaches

2. Acquiring the knowledge necessary to understand the functioning of wagon or coach assemblies

3. Application of knowledge in the design, development, repair and maintenance of wagons and coaches

learning outcomes
After completion of the course the student should be able to:

1. Explain the functional and structural characteristics of various types of rolling stock.

2. Explain the tasks and functioning principles of the assemblies of the rail vehicles.

3. Identify actions required to resolve failures in operation and maintenance of rail vehicles.

4. Apply appropriate regulations and standards for design and maintenance of railway vehicles.

5. Applicate computer tools for calculating and designing rail vehicles.

theoretical teaching
General characteristics of the elastic suspension system. Suspension with helical springs. Suspension with leaf springs. Suspension with rubber springs. Air suspension system. Elastic pendulum-based systems. Natural and forced tilt of the rail vehicles in curves. Torsional characteristics of the rail vehicles. Damping elements. Active and passive suspension systems.

Draw-buff gear. Design and mechanical characteristics of buffers. Draw gear. Automatic couplers. Equipment of the passenger coaches. Doors, windows, stairs. Heating and air conditioning requirements and design performance. Electrical installation. Passenger information system. Fire protection. Noise inside the vehicle and noise emission. Specifics of passenger coaches for high speeds. Specifics of the freight wagons for increased speeds.

practical teaching
Initial requirements and general constraints for design of the elastic suspension system. Design of suspension springs system with double ring links. Design of the systems with helical springs. Design of the systems with rubber springs. Air suspension system design. Determination of the torsional characteristics of the rail vehicle. Design of the anti roll system. Active and passive tilt systems.

Design of buffers. Limitation of space on the ends of the wagon. Calculation of the buffer plates dimensions. Calculation of the draw gear angular deflection in curves. Gangway connection systems. Examples of design solutions for different equipment of the wagons.

prerequisite
Previously passed course Railway vehicles 1.

learning resources
D. Milkovic, Rail vehicles, hand-out
G. Simic, Instructions for writing student papers, hand-out
For preparation tasks as a basis should be used the appropriate regulations and standards

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 2
calculation tasks: 0
seminar works: 3
project design: 9
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 30
final exam: 35
requirements to take the exam (number of points): 0

references

Railway vehicles maintenance

ID: MSc-0234
responsible/holder professor: Lučanin J. Vojkan
teaching professor/s: Lučanin J. Vojkan, Tanasković D. Jovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals
Upon completion of the course the student should be able to:

1. Explain the basic concepts related to the reliability of rail vehicles.

2. Explain the basic concepts related to the maintenance of rail vehicles.

3. Explain the tasks and practices of the workshop for the maintenance of railway vehicles.

4. Perform appropriate calculations related to maintenance of rail vehicles.

5. Apply appropriate tools for computer calculations of electric and diesel electric locomotives.

learning outcomes
After successfully finishing of course students would be able to:

- define basic terms which are important for understanding of reliability and maintenance of railway vehicles;
- choose an appropriate approach to the maintenance of railway vehicles;
- solve practical problems of maintenance of railway vehicles directed to organisation, implementation of projected activities as well as implementation of knowledge in field of reliability, information and expert systems;
- make detailed scheme of the maintenance workshop of railway vehicles by using modern PC tools;
- discuss about possibilities of improving of the maintenance process using modern methods for monitoring of system failure.

theoretical teaching
Theoretical basis of reliability.Prediction reliability.Methods of determining the distribution of the data set.Setting reliability requirements and measures for their achievement for rail vehicles.The concept of constructing the basis of reliability. Maintenance of technical systems.Engineering maintenance.Maintenance and life cycle of railway vehicles.Maintenance process.Overview of the developed concept of maintenance railway vehicles in the world.Analysis and assessment of maintenance.Design of technical systems for maintenance.Management of spare parts.Technology in railway vehicles maintenance.Diagnosis of railway vehicles.Maintenance management.The organization of railway repair workshops.Depots.Warehouses.Information and expert systems in the maintenance of rail vehicles.

practical teaching
Understanding the examples from the theory of reliability of the system.Application of the railway vehicles.Examples of the material.Methods of determining the distribution of the data set.Setting reliability requirements and measures for their achievement for rail vehicles.Examples of the completed material.Application of computers in determining the reliability and Information and expert systems in the maintenance of railway vehicles.Creating a computer program - Information and expert system in the maintenance of railway vehicles.Visit the workshop for the maintenance of diesel and electric vehicles.Understanding the system of maintenance of rail vehicles.

prerequisite
Nothing

learning resources
It is necessary the use of textbooks, manuals for the project, a handout, computers and the Internet.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 5
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 15
project design: 30
final exam: 35
requirements to take the exam (number of points): 35

references
Dusan Stamenkovic, Maintenance of railway vehicles, Faculty of Mechanical Engineering - Nis, Serbia, 2011.
Slobodan Muzdeka, Logistic - Logistics engineering-reliability, maintainability, readiness, integrated technical security, Belgrade, 1981.
Nikola Vujanovic, Theory of reliability of technical systems, Belgrade, 1990.

Skill Praxis M - ZEM

ID: MSc-1301
responsible/holder professor: Tanasković D. Jovan
teaching professor/s: Lučanin J. Vojkan, Milković D. Dragan, Tanasković D. Jovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: project design
parent department: railway mechanical engineering

goals
Students practical experience and stay in the environment in which the student will realize his professional career. Identifying the basic functions of the business system in the field of development, designing, production, maintenance of railway vehicles, as well as the roles and tasks of mechanical engineer in such a business system.

learning outcomes
After successfully finishing of skill praxis students would be able to:

- define and discuss about design processes, production and maintenance of railway vehicles;
- implementation of acquired practical knowledge about way of organization and functioning of producers and maintenance workshop of railway vehicles in the future professional career;
- recognize models of communication with colleagues and flows of business information;
- evaluate of the importance of team approach in resolving of problems, improving of production processes and maintenance of railway vehicles.

theoretical teaching
Introduce students to practical training realization concept and prepare them for all units of prescribed curriculum and way of communication. Guidelines for diary keeping and report writing are given and students record are created.

practical teaching
Practical work involves work in organizations with various activities in relations with mechanical engineering. Selection of thematic areas, commercial or research organizations students carrier out in consultation with the relevant teacher. Generally a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations for maintenance of railway vehicles and in some of the laboratories at Faculty of Mechanical Engineering. The practice may also be done abroad. During practice, students must keep a diary in which have to enter a description of the tasks performed, the conclusions and observations. Following the practice must make a report which have to present to the relevant teacher. The report is submitted in the form of the paper.

prerequisite
Nothing

learning resources
Guide for keeping a practice diary and writing final report.

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 80
> auditory exercises: 0
> laboratory exercises: 0

calculation tasks: 0
seminar works: 0
project design: 80
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 0

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 70
final exam: 30
requirements to take the exam (number of points): 30

references

Theory of Traction

ID: MSc-1187
responsible/holder professor: Tanasković D. Jovan
teaching professor/s: Lučanin J. Vojkan, Tanasković D. Jovan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals
Knowledge acquiring in designing, production and exploitation of railway vehicle, in designing of rail tracks as well as the organization of railway traffic.

Introducing students with:

- The Forces acting on railway vehicle,

- Calculation methods for traction, resistance and braking force and the velocity, using modern computer tools,

- The methods for determination of optimal movement conditions of railway vehicles,

- Ways of solving practical problems related to the movement of railway vehicles and rail tracks configuration.

learning outcomes
After successfully finishing of course students would be able to:

- define tasks and way of functioning elements, subassemblies and assemblies of tractive vehicles;

- calculate tractive effort, train resistance, braking force and velocity of railway vehicle using special software package;

- discuss about advantages and disadvantages of the different types of power transmissions and their characteristics;

- assessment of advantages and disadvantages of different types of coupling which can be used in tractive railway vehicles;

- implementation of regulations and standards in the field of railway vehicle traction.

theoretical teaching
Characteristics of the railway transport, Analysis of the influencing factors on the traction forces, Transmission of traction forces – adhesion as requirement for traction forces, Traction features of high-speed railway vehicles, Traction features of the diesel traction railway vehicles, Basic characteristics of running gear and drive of traction vehicle, Traction features of the electric traction railway vehicles, Train resistance – main and additional resistance, High speeds train resistance, Railway vehicles braking force – characteristics of the braking process, Equations of the train.

practical teaching
Practical learning, Auditory exercises (Introduction to the examples in modern railway transport, Recapitulation of learned material necessary for passing this subject (mechanics, machine elements and electrical engineering), Using of computer tools to solve problems in train traction, Guidance of wheel set in track, The relative velocity of wheel set in relation to the rail, Forces at the wheel set edge point and the contact point of the wheel-rail , Basic characteristics of traction features, adhesion as requirements for traction forces , Basic characteristics of diesel and electric traction railway vehicles, The resistance forces in motion the train, Task (Determination of traction characteristics of the diesel

traction vehicles with mechanical and hydraulic power transmission, Determination of traction characteristics of the diesel traction vehicles with electric power transmission, Determination of traction characteristics of the electric traction vehicle, Analytical determination of the resistance force when moving train, Solving differential equations of train), Discussions and workshops.

prerequisite
Nothing

learning resources
Literature that is available in the Faculty Bookstore and Library; Handouts available on lectures; Internet resources (KOBSON).

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 9
laboratory exercises: 0
calculation tasks: 11
seminar works: 0
project design: 0
consultations: 5
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 30
seminar works: 5
project design: 0
final exam: 35
requirements to take the exam (number of points): 35

references
Lucanin, V., Theory of Traction, Faculty of Mechanical Engineering, Belgrade, 1996.
Andreas Steimel, Electric Traction - Motive Power and Energy Supply, Oldenbourg Industrieverlag Munich, 2008.
Brenna M., Foiadelli F., Zaninelli D., Electrical Railway Transportation Systems, IEEE PRESS, Wiley, 2018.

Urban and special rail vehicles

ID: MSc-1191
responsible/holder professor: Milković D. Dragan
teaching professor/s: Milković D. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: railway mechanical engineering

goals
1. Understanding the specifics of urban rail vehicles.

2. Understanding the various types of special rail vehicles.

3. Qualification for the application of acquired knowledge in the design, development, repair and maintenance of urban rail vehicles and special vehicles

learning outcomes
After completion of the course the student should be able to:

1. Explain the functional and design specificity of various types of urban rail vehicles.

2. Explain the tasks and functionality of various types of special rail vehicles.

3. Explain the specific technologies and technical requirements in combined transport.

4. Apply appropriate regulations and standards in the design and maintenance of urban rail vehicles and special rail vehicles.

theoretical teaching
Railway multi-modal transport. Transport unit types. Wagons for combined transport of containers and swap bodies. Wagons for the transportation of semi-trailers with vertical handling. Rolling stock and systems for the transport of complete road vehicles by rail. Semitrailers on bogies. Gauges for combined transport.

Special wagons: tank-wagons, refrigerating wagons, hopper wagons, articulated multiple wagon units...- technical requirements and technical solutions.

The forms of urban and suburban public transport: tram, light rail, metro, regional trains - requirements and specifications. Specific requirements: loads, acceleration, braking, line geometry, platform heights. Low floor design. Doors, staircases, vestibules. Articulation designs. Crash worthy design. Specifics of bogie design for low floor and articulated vehicles. Tyred running gear. Automated metro system requirements. Monorails.

Vehicles on the principle of magnetic levitation: basic principles of magnetic suspension, propulsion and guidance. Systems: Transrapid, MLX, Linimo...-technical solutions.

practical teaching
Division and classification of the transport units for combined transport: pallets, containers, swap bodies. Stability during loading or unloading of wagons with horizontal transshipment. The determination of the gauge code for semi-trailers in combined transport by rail. Analysis of the design parameters of the wagons for the combined transport.

Dimensioning requirements of the tanks by RID regulations. Valve system variants of the tanks for the transportation of the dangerous goods.

Urban rail vehicles. Geometry of the basic transport unit. Relationship vehicle-platform. Examples of the running gear of urban rail vehicles. Specifics of running through curves with small radius. Design examples of the unconventional rail systems.

Design concepts of the magnetic levitating vehicles.

prerequisite
Previously passed exam of Railway cars 1 or Theory of traction.

learning resources
Simic, G., Urban and special railway vehicles, hand-out

EN standards, UIC and RID regulations from the subject field.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 0
calculation tasks: 4
seminar works: 3
project design: 0
consultations: 6
discussion and workshop: 5
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 50
laboratory exercises: 0
calculation tasks: 10
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

STRENGTH OF STRUCTURES

Basics of Composite Materials Mechanics

ID: MSc-0721
responsible/holder professor: Balać M. Igor
teaching professor/s: Balać M. Igor, Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: strength of structures

goals
Main objective of the course is to teach students the fundamental principles of the mechanics of composite materials. This theory is further applied to design and analyze unidirectional and multidirectional fiber composite laminates. Within the course the basic issues associated with the design of composite materials will be studied as well. A special attention will be devoted to the practical stress and strain analysis of mechanical components made out of composite materials. Issues connected to the characterization of mechanical properties of composite materials will be tackled as well.

learning outcomes
1. Within the course students will learn various methods of the assessment of elastic constants entering into constitutive equations which describe mechanical behavior of composite materials. Problems of determination of macro behavior of composite materials starting from known properties of components entering into it will be tackled as well. The course will cover also the study of different failure criteria for various types of composite materials.

2. Students will learn how to perform stress – strain analysis of laminate composite materials.

3. The course will devote some attention to the influence of the environmental conditions (e.g. temperature and humidity) to the variation of mechanical properties of composite materials. This will be studied with a special focus on unidirectional and multidirectional composite laminates.

4. By completing this course students will become familiar with basic concepts of mechanics of composite materials. A special attention will be devoted to the practical procedures of stress analysis of mechanical components made out of composite materials, with numerical implementation of the most frequently used techniques.

theoretical teaching
1. Introduction to composite materials: Basic concepts. Classification, main characteristics and the most frequent applications of composite materials in modern engineering.

2. Macro mechanical elastic behavior of unidirectional lamina composites. The Hooke's Law for a two dimensional lamina. Determining stiffness of parallel arrays of fibers in matrix. Rules of mixture. Off-axis properties of a lamina.

3. Determining strength of unidirectional lamina. Analysis of failure criteria. Diverse failure criteria and their applications.

4. Macro mechanical elastic behavior of multidirectional composite laminates. Stress and strain analysis of single lamina, and of the entire composite material. General laminate plate theory. Studding of coupling effects – coupled flexure and torsion.

5. Stress – strain and failure analysis of multidirectional composite materials. Strength of lamina under tension and shear. Inter-laminar stresses. Laminate strength analysis. First ply failure.

practical teaching

1. Analytical examples of the assessment of macro mechanical properties of the composite materials.

2. Examples of the Hooke's law theory applied to the two dimensional unidirectional laminates. Determining of the stiffness matrix for the composite material.

3. Numerical exercises of stress strain analysis of laminate composites. Examples of determination of local and global values for stress and strain.

4. Numerical examples of determination of the ultimate strength using diverse failure criteria. Practical applications of failure theory to the ultimate strength calculations of mechanical components made out of composite materials.

5. Examples of numerical implementations of diverse modeling techniques of composite materials into the available codes. Comparison of numerical and analytical predictions of composite material component behavior.

prerequisite

Taken exams:

Strength of materials,

The base of strenght of constructions.

learning resources

The whole course material is well covered by hand-outs written by the lecturers of the course. Every attendee of the course will be provided his/hers own copy of the hand-outs. Apart of this, all the below mentioned books can be borrowed from the lecturers during the course or ordered on some relevant websites.

number of hours: 75

active teaching (theoretical): 35
lectures: 25
elaboration and examples (revision): 10

active teaching (practical): 35
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 15
seminar works: 10
project design: 0
consultations: 10
discussion and workshop: 0
research: 0

knowledge checks: 5
check and assessment of calculation tasks: 1
check and assessment of lab reports: 0
check and assessment of seminar works: 1
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 1
final exam: 1

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 40

laboratory exercises: 0
calculation tasks: 5
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

"Mechanics of composite materials", Autar K. Kaw
"Mechanics and analysis of composite materials", Valery Vasiliev and Evgeny Morozov
"Mechanics of Elastic Composites", Nicolaie Dan Cristescu, Eduard-Marius Craciun and Eugen Soós
"Mechanics of Composite Materials with MATLAB" George Z. Voyiadjis and Peter I. Kattan
"Mechanics of composite materials", Robert M. Jones

Theory of elasticity

ID: MSc-0903
responsible/holder professor: Milošević-Mitić O. Vesna
teaching professor/s: Anđelić M. Nina, Milošević-Mitić O. Vesna
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: strength of structures

goals
The purpose of this course is that students understand and learn the basic concepts of the theory of elasticity.

They will acquire the basis of the tensor method, too.

Students will enable to model and solve some reological problems.

Through understanding the reological processes they will be able to use computer programs in this field.

learning outcomes
- By negotiation of this program, students will master some basic methods and procedures of the theory of elasticity and of the tensor method.

- They will be able to calculate stress components on the base of balance equations and to form appropriate tensors of stress and strain for an ideal elastic body.

- They will be introduced with principal stresses (intensity, position) and with maximum shear stress.

- They will be able to calculate main strains.

- Students will master application of hypothesis about the collapse of material.

- They will understand elasticity and stiffness matrixes.

- They will be able to solve some real problems related to thin simply supported plates.

theoretical teaching
Introduction. The concept of stress. Cauchy's principle. Stress components in Cartesian and cylindrical coordinate system. Stress tensor. Equilibrium equation in Cartesian and cylindrical coordinate system. Stresses in an arbitrary plane - transformation of stress tensor. Principal stresses. Stress invariants. Volume and deviator components. The maximum shear stress. Plane state of stress. Deformation, Lagrange's strain. Small deformation. Geometric interpretation. Compatibility equations. The main deformations. Volume and deviator components. Hypotheses about the collapse of material. Plane state of strain. The rate of strain. Linear elasticity. Hooke's law. Modulue of sliding. Lame 'constants. Poisson's ratio. Thin plates. Reological models and modeling.

practical teaching
Determination of the stress components on the base of balance equations. Determination of the stress components in oblique plane - transformation of stress tensor. Principal stresses, the intensity, the position. The maximum shear stress, the intensity and position. Stress invariants. Deformation by Lagrange and Euler. Calculation of the main strains. Application of hypothesis. Tensors of stress and strain for an ideal elastic body. Thin simply supported plates.

prerequisite
Set by the Curriculum of the study program

learning resources
Handouts from the website of the Department for Strength of the constructions

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 5
seminar works: 5
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 40
laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
final exam: 40
requirements to take the exam (number of points): 20

references
Theory of elasticity, T. Atanacković
Theory of elasticity, S. Tymoshenko, J. N. Gudier
Sets of the structural strength, T. Maneski, V. Milosevic-Mitic, D. Ostric

Theory of finite element method

ID: MSc-1133
responsible/holder professor: Buljak V. Vladimir
teaching professor/s: Buljak V. Vladimir, Grbović M. Aleksandar
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: strength of structures

goals
The objective of this course is to provide thorough methodological introduction to the Finite Element Method. Within the introductory part students will get familiar with the application of this method for solving boundary value problems in the elasticity. Emphasis will be given to formulation of weak form of problems both in statics and dynamics. The main goal of the course is to present to the students how displacement based finite elements can be used to solve linear problems. Detailed derivation of stiffness matrix will be shown with reference to finite elements of various types (both structural and continuum elements). Various technique for the application of boundary conditions, and different methods for solving linear algebraic equations will be outlined. Post processing techniques and recovery of strain and stress fields based on nodal displacements for finite elements of different types will be presented in a detailed manner. In closing sessions of the course students will be shown some of the most popular commercial software used for static and dynamic analysis of structures.

learning outcomes
Upon completing the course students will be able to:

-Write computer codes for the assembling of stiffness matrix for truss-, beam-, frame- and shell-elements, as well as continuum 2-dimensional and 3-dimensional finite elements;

-Perform both static and dynamic analysis of simple structures within personally developed computer codes;

-Write computer codes for the stress and strain recovery based on linear, small-deformation theory, starting from resulting nodal displacements;

-Understand basics on which most commercial software are build and use them for performing static and dynamic analysis of more complex structures.

theoretical teaching
Introduction to numerical modeling. Principle of virtual work and its application to the formulation of weak form of the problem. Interpolation functions for representing the displacement field over finite element. Assembling of element and global stiffness matrix. Dicretization for Lagrangian types of meshes. Methods for solving the resulting system of linear algebraic equations. Stress and strain recovery from nodal displacement results. Solutions for dynamic problems. Implicit and explicit scheme for time integration. Stability of the solution.

practical teaching
Writing computer codes in MATLAB software, for truss-, beam, frame-, shell-elements, as well as continuum 2D and 3D elements. Assembling of global stiffness matrix and mass matrix. Application of boundary conditions: concept of reduced stiffness matrix, and alternative solution with Lagrange-multipliers technique. Developing codes for strain and stress recovery. Static and dynamic analysis of structures.

prerequisite
Passed exam Theory of elasticity

learning resources
Each student should have the access to the personal computer.

number of hours: 75

active teaching (theoretical): 30
lectures: 28
elaboration and examples (revision): 2

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 10
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 5
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 20
laboratory exercises: 5
calculation tasks: 5
seminar works: 0
project design: 0
final exam: 70
requirements to take the exam (number of points): 0

references
"The finite element method - a practical course" G.R. Liu S. S. Quek.
"An Introduction to the Finite Element Method" J.N. Reddy
"The Finite Element Method: Linear Static and Dynamic Finite Element Analysis", T. Hughes
"Finite Element Method: Volume 1" O. C. Zienkiewicz and R. L. Taylor

THEORY OF MACHANISMS AND MACHINES

Design of mechanisms and manipulators in the food industry

ID: MSc-1317
responsible/holder professor: Jeli V. Zorana
teaching professor/s: Jeli V. Zorana, Stojićević D. Miša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: theory of machanisms and machines

goals

mastering the knowledge of design and construction of all types of mechanisms, with special emphasis on cam and Maltese mechanisms; acquiring the ability to analyze them within the machines and devices used in the food industry; getting acquainted with the types and manner of operation of manipulators, as well as with the possibilities of their construction with simpler functions; introduction and analysis of manipulative processes in the food industry.

learning outcomes

The student has mastered the procedures for the construction of mechanisms that are mostly used in machines and devices of the food industry, as well as for connecting the work of individual machines in production lines.

The student is acquainted with the principles of operation of various software packages (which will deal with modeling and analysis of mechanisms and manipulators) and give him the opportunity to easily master some other packages for modeling and generating the movement of mechanisms in practice.

theoretical teaching

A brief review of kinematic pairs and plane mechanisms; equivalent mechanisms. Cam mechanisms; cam plate: translational and rotating; translational and rotating lifters: with rounding, roller or disc; law of motion, velocity, acceleration, force; synthesis of cam plates.

Maltese mechanisms; gear and toothed mechanisms; law of motion, velocity, acceleration, force; synthesis mechanism. Spatial mechanisms; structure of mechanisms; closed and open kinematic chains; mechanisms with a number of independent drives.

Manipulators with 5-class kinematic pairs; spatial three-membered kinematic chains with independent drives; manipulators of the type: TTT, TRT, TRR, RRT and RRR and service space. Creating a part of the program for optimal synthesis of mechanisms in MATLAB for special path shapes of plane mechanisms. Synthesis of spatial manipulator drives; creating the specified types of manipulators in the SolidWorks software package; defining the desired law of movement of the workpiece: 1-expressions, 2-series of oriented positions; reading the law of changes of internal coordinates of the manipulator; defining the manipulator drive. Development of Motion Analysis and display of manipulators.

practical teaching

Equivalent mechanisms; replacing the higher kinematic pair with a kinematic chain with lower kinematic pairs. Camshaft construction; diagram construction: times, velocities and accelerations; using programs in ACAD to synthesize cam mechanisms.

Construction of the Maltese mechanism; choice of Maltese mechanism; diagrams: movements, velocities and accelerations; defining the parameters of the toothed wheel and the grasshopper. Construction of a mechanism with a characteristic trajectory; synthesis of the mechanism in MATLAB and construction in the SolidWorks software package for a given shape of the working part of the path.

Construction of manipulators TTT, TRT, ... in SolidWorks software package; defining independent plants; determination of forces in kinematic pairs; defining driving forces and moments.

Construction of manipulators TTT, TRT, ... according to the given law of movement of the workpiece (function or through oriented positions). Development of a specific project of replacing a manipulative action in the post-food process with an action performed by a specific manipulator.

prerequisite
A desirable condition is passing the course Designing Mechanisms

learning resources
Script: Design of mechanisms and manipulators in the food industry; author: Dr. Jeli Zorana, Boris Kosić; Necessary additional materials (handouts, task settings, seminar papers, etc.) are provided on web pages or reproduced on paper. Larger electronic materials can be made available to students in direct contact. Classes are realized by combining video display and blackboard.

number of hours: 75

active teaching (theoretical): 20
lectures: 15
elaboration and examples (revision): 5

active teaching (practical): 25
auditory exercises: 2
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 5
discussion and workshop: 2
research: 2

knowledge checks: 30
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 5
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 35
requirements to take the exam (number of points): 40

references
Kinematic Geometry of Mechanisms, Hunt K.H, Oxford, 1978

Engineering Condition Monitoring

ID: MSc-0989
responsible/holder professor: Šiniković B. Goran
teaching professor/s: Šiniković B. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: theory of machanisms and machines

goals
Students are to acquire necessary knowledge to trouble-shoot the machinery, reveal main cause of malfunction and prescribe remedial action. Introduction of equipment and devices for engineering diagnosis and skills development for applying them.

learning outcomes
In this course students prepare to accumulate engineering knowledge and skill to approach an object, use the technical documentation to understand system operation, apply appropriate methods of check out, collect relevant data, compare the the results with ISO proposed norms, make a decision and specify the list of remedial action.

theoretical teaching
Lectures: Description of common objects of diagnosis. Typical machinery composition. Subassemblies. Machinery outlines. Different diagnostic models, monitoring priorities and optimization. Diagnosis of: distributing networks for propelants, compressed air, gases, steam, lubricants, etc. Site measurements. Description and classification of different kind of measurements. Diagnostic algorithms and machinery structurizing. Selection of diagnostic parameters. Diagnostic devices. Functions and accessories. Schedule of inspection. Critical machine operating range. Preliminary measurements. Troubleshooting. Reporting. Overhaul and rehabilitaion program definition. ISO verification. Run out check up. NDT inspection. Lubricants inspection.

practical teaching
Exercises, Lab work: Typical machinery - generators, blowers, pumps, compressors, turbines, transportation lines. Site measurements: temperature, pressure, fluid flow, velocity, position, acceleration, displacement. Site diagnosis: troubleshooting, rehabilitation list. Geometry check out: shape, position and dimensional tolerances. NDT inspection: magnetic particles, chemical agents, ultrasound. Vibrodiagnosis: spectral analysis, peak detection, phase lag measurement. Technical liquids and gases analysis. Proactive strategy of maintenance.

prerequisite
No prerequisites

learning resources
G. Sinikovic, Diagnostic Machinary, Faculty of Mechanical Engineering Belgrade, 2020,

A. Veg, G. Sinikovic, Manuscript "Fundamentals of technical diagnosis"

A.Veg, G.Sinikovic, Handbook of vibrodiagnosis

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 24
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 6
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 8
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 30
laboratory exercises: 25
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Food Processing Machines

ID: MSc-1175
responsible/holder professor: Jeli V. Zorana
teaching professor/s: Jeli V. Zorana, Stojićević D. Miša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: theory of machanisms and machines

goals
1. Getting acquainted with the basic concepts necessary for dealing with matter in this field. 2. Acquiring skills in preparation of modern design programs for designing and analyzing the operation of food equipment and plants. 3. Developing students' creative abilities to design food systems, machines and systems.

learning outcomes
1. Knowledge and understanding of the problem of food machines 2. Analyzing existing solutions and their effects 3. Linking knowledge from various fields of technology, tracking the newspapers and applying them 4. Adopting practical knowledge 5. Solving concrete problems in the production of food machines.

theoretical teaching
Acquiring knowledge about food products in general and their classification, understanding of basic technological requirements and ways of their realization, grain processing machinery, constructive characteristics and examination of various types of mills as characteristic machines in the field of grain processing, machinery in the confectionery industry, overview of characteristic types of machines for different types of confectionery products, their working principles and technical characteristics, transport systems in the confectionery industry, connection of individual machines in these cation of the parent entity for the production of confectionery products, automated production lines for hard biscuits and crackers, the characteristics of machines for test preparation, test processing and obtaining the final form pasta making machines for fruit and vegetable processing, milk processing machinery, machinery for meat processing.

practical teaching
Practical exercises which include familiarization with the basic technical and technological characteristics of typical representatives of food processing machines for grain processing (mills and sieves), machinery in the baking industry (mixers, dividers, fermentation chambers, formations), machine in the confectionery industry (laminating machines, shaping, cutting), a fruit and vegetable processing machine, a milk processing machine and a meat processing machine. Preparation of a project which includes defining the project task, the necessary calculations and the production of documentation of assemblies or complete devices.

prerequisite
There are no special conditions for attending the course, preferably listened to and passed Basic Technological Operations in Food Engineering.

learning resources
Skripta u pripremi. Za uspešno savladavanje predmeta neophodno je korišćenje uputstva za izradu projekata, handout-a, Ineternet resursa i video zapisa.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 8
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 6
colloquium, with assessment: 4
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 30
requirements to take the exam (number of points): 44

references
Food Machines, Peter Batchelor, 2009

Packaging Machines

ID: MSc-1318
responsible/holder professor: Šiniković B. Goran
teaching professor/s: Šiniković B. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: project design
parent department: theory of machanisms and machines

goals
Getting started with the machines that achieve these technological solutions. Acquiring the necessary knowledge in the field of thermal processes that are necessary for certain types of packages. Introduction to various techniques for normal and sterile package closing.

learning outcomes
This course gives the knowledge necessary for the maintenance of various packaging machinery that can be found in food and other industries. It also gives the necessary knowledge to the investors that order and purchase packaging machines. Besides this, students get all the specific technological, process and design knowledge for projecting and design of packaging machines.

theoretical teaching
Worm dozers and scales for packaging machines - dependence of the worm shape and the structure and quality of dozed material will be defined. Special attention will be paid to scales. Packaging lines - a combination of blowing, filling and sealing machines. Packaging machines with extrusion tubes - specific packaging line in which the container is made of extruded plastic tubes. Packaging machines with a heat extraction vessel - the specific packaging line in which the vessel is made by shallow or deep extraction of plastic foil.

practical teaching
Packages obtained by injection of pellets. Packages obtained by extraction of plastic foil. Packages obtained by tubes extruding. Packaging lines - 2: A combination of machines for blowing, filling and sealing. Packaging lines - 1: A combination machine for blowing, filling and sealing, pneumatic and hydraulic schemes. Dozers, palletizers, sealing machines, wrapping machines for stretch and shrink film. Classification of packaging machines. Industrial packaging. Multifunctional packing machines - machines for filling and sealing. Gravimetric machines - worm dozers and scales in packaging machines. Dependence of the worm shape and the structure and quality of dozed material will be defined. Scales will be treated in particular.

Machines for grouping and ungrouping aggregate packages.

prerequisite
To attend classes of the subject Packaging machines, no condition is necessary.

learning resources
To successfully master this subject, it is necessary to use a textbook that is in preparation, instructions for preparation of seminar papers, handouts, Internet resources.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 0
laboratory exercises: 18
calculation tasks: 0
seminar works: 5
project design: 0
consultations: 7
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 4
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 20
laboratory exercises: 25
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Lj. Miladinovic, M. Stoimenov, A. Veg, "Packaging Machines", monography
Geoffrey Boothroyd, Assembly Automation and Product Design, Taylor & Francis, 2005.
Andreas Gäotzendorfer, Vibrated granular matter: transport, fluidization, and patterns, Universität Bayreuth, 2007.

Product Aestetics

ID: MSc-0270
responsible/holder professor: Popkonstantinović D. Branislav
teaching professor/s: Popkonstantinović D. Branislav, Stojićević D. Miša
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: theory of machanisms and machines

goals
Introduce students to the standards and laws of aesthetics in the process of product design, recognizing the subjective and objective factors of establishing the aesthetic judgement; introduction to the cultural and historical aspects and schools of aesthetics; treatment of aesthetic elements and principles, the study of geometric harmony laws, the use of traditional and modern means of creating aesthetic properties; introduction to the features of modern graphical signs and aesthetic properties of packaging and advertising.

learning outcomes
Student has gained the ability of aesthetic evaluation and the formation of aesthetic judgement, through theoretical and practical courses, student is trained to creatively use both abstract elements and principles of aesthetics and practicality (classical and modern) means of creating aesthetic characteristics of the product;

theoretical teaching
Aesthetics definition and etymology of the name; concept, factors and aesthetic significance of the judgement of sentiment and aesthetic standards; explanation of the relativity of aesthetic judgement through a short presentation on the history and origin of aesthetics; aesthetics as a factor of visual communications, detailed analysis of the aesthetic elements of Product design, processing and analysis of basic aesthetic principles of Products design; processing of geometric principles as essential factors of aesthetics of visual communication; concept of the composition harmony, methods of creating and presenting aesthetic properties (classical and modern); sketching and drawing the basic principles of oblique projections, orthogonal axonometry, central projections and prospective, Principles of computer modeling using the appropriate forms CAD software; the concept of modern graphical signs and symbols; the role of graphic symbols in the context of contemporary visual communications; aesthetics of signs, symbols and meanings; aesthetic properties of product packaging, advertising and product presentations;

practical teaching
Independent analysis, creation and presentation of examples on aesthetic universal attitude and the basic principles of induction of aesthetic value, aesthetic evaluation, discussion on cultural and historical aspects of aesthetics, training the use of aesthetic elements and principles; constructive analysis of classical geometrical laws of aesthetics; exercises using classical and contemporary means of creating and presenting the aesthetic properties of products; exercise in creating graphical symbols and signs with an emphasis on aesthetic visual meaning;

prerequisite
Required: Passed courses Constructive Geometry and Engineering Graphics. Desirable: Passed courses Machine elements 1 and 2

learning resources
Script: The aesthetics of the product, by Branislav Popkonstantinović;

need additional materials (handouts, exercises, essay titles, etc..) are given at the web site or reproduced on paper.

Large-scale electronic materials can be made available to students in direct contact. Teaching is done by combining video images and tables.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 7
laboratory exercises: 6
calculation tasks: 7
seminar works: 7
project design: 0
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 40
laboratory exercises: 10
calculation tasks: 10
seminar works: 10
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Skill Praxis M - PRM

ID: MSc-1176
responsible/holder professor: Šiniković B. Goran
teaching professor/s: Veg A. Emil, Jeli V. Zorana, Popkonstantinović D. Branislav, Stojićević D. Miša, Šiniković B. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: theory of machanisms and machines

goals
1. Obtaining practical knowledge in the field of food processes and machines.
2. Getting knowledge about the machine materials necessary for use in the manufacture of food machines.
3. Development of students' creative abilities for designing food devices, machines and systems,by analysis of structures and exploitation characteristics of food machines and plants.

learning outcomes
By mastering the study program student acquires the ability:

- Analysis of existing solutions and their effects.
- Acquisition of practical knowledge.
- Application of acquired knowledge in practice.

theoretical teaching
Introduction to the subject. Specificity of the food industry. Basic technological operations related to the production of food products. Systems and plants for the production of food products. Specificity, characteristics and construction of food production machines.

Manufacture of food products. Production of flour, sugar, oil, etc. Machines usually used in the production of food products. Processing of fruits, vegetables, milk and meat. Machines for processing fruits, vegetables, milk and meat. Manufacture of bakery and confectionery products. Baking and confectionery machines and lines.

practical teaching
First seminar paper and second seminar work. Introduction with the production process in the systems involved in the production of food products covered by lectures. Tour companies that design and construct plants, as well as the production of food processing equipment. Getting to know the work of companies that deal with the design and construction of the plant, as well as the production of equipment for the production of food products.

Consultations: consideration of completed active teaching and students' questions

prerequisite
No additional conditions for attending the course Professional Practice M-PRM

learning resources
In order to successfully master the subject, it is necessary to use Internet resources, prospect material of producers and users of food equipment and videos.

number of hours: 90

> **active teaching (theoretical):** 25
> lectures: 15
> elaboration and examples (revision): 10

active teaching (practical): 55
auditory exercises: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 40
project design: 0
consultations: 15
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 6
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 4

assessment of knowledge (maximum number of points - 100)
feedback during course study: 20
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 50
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

THERMAL POWER ENGINEERING

Computer simulations of thermalhydraulic processes and CFD

ID: MSc-1320
responsible/holder professor: Milivojević S. Sanja
teaching professor/s: Milivojević S. Sanja, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
The aim is acquiring knowledge and skills for development and application of analytical and numerical models of thermal-hydraulic processes in energy, thermal and process equipment,as well as application of numerical methods for the simulation and analyses of one-phase and two-phase systems in pipelines and plant equipment, including the methods of Computational Fluid Dynamics - CFD.

learning outcomes
The students are trained to perform computer simulation and analyses of heat transfer and fluid flow processes of one-phase and two-phase gas-liquid systems with and without phase transitions in energy, thermal and process equipment.

theoretical teaching
Modelling of thermal and flow processes with lumped and distributed parameters. Balance equations of mass, momentum and energy and constitutive correlations for interface transfer processes. Explicit and implicit numerical methods for the solving of Cauchy problems with defined initial conditions in cases of the lumped parameter models. The method of characteristics for the solving of hyperbolic system of partial differential equations. The application of the method of control volumes of the SIMPLE type for the solving of elliptic and parabolic multidimensional models with distributed parameters. Numerical grid generation. Graphical presentation of results.

practical teaching
Development of the models with lumped parameters for the pressure dynamics prediction in the pressurized vessels filled with one phase compressible fluid or two-phase mixture of liquid and condensing vapour. Numerical simulation of pressure transients in the pressurizer, in the feedwater tank and the drum of a steam boiler. Development of models with distributed parameters for one-phase and two-phase flows with or without phase transitions. Numerical simulations of pressure and temperature waves propagation in pipeline networks. Computer simulations and analyses of multidimensional two-phase flows in steam generators, evaporators, condensers, heat exchangers, etc.

prerequisite
Attended courses in Fluid Mechanics, Thermodynamics, and Numerical Methods.

learning resources
Course handouts. Stevanović, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, Monograph, Faculty of Mechanical Engineering, Belgrade, 2006. Computer equipment. Software for numerical solving of systems of differential equations of various types. Software for simulation and analyses of pressure transients in pipeline networks and pressurized vessels. Software for simulation and analyses of multidimensional two-phase flows.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 30
laboratory exercises: 35
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Versteeg, H.K., Malalasekera, W., An introduction to Computational Fluid Dynamics, Longman Group Ltd., Harlow, 1995.
Wulff, W., Computational methods for multiphase flow, Multiphase Science and Technology, Vol. 5, Begell House, 1990.
Streeter, V.L., Wylie, E.B., Hydraulic Transients, McGraw Hill, New York, 1967.
Tannehill, J.C., Anderson, D.A., Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, Taylor&Francis, New York, 1997.
Stevanovic, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, University of Belgrade, Faculty of Mechanical Engineering, 2006.

Energy Planning

ID: MSc-0105
responsible/holder professor: Stevanović D. Vladimir
teaching professor/s: Milivojević S. Sanja, Petrović V. Milan, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal power engineering

goals
The aims of the subject are to master the methods for the analyses and planning of the macro energy systems at the level of economy and industry sectors, regions and the country, including analyses and formation of energy balances, prediction of energy flows and the structure of energy consumption, classification of energy carriers and indicators of energy consumption, the relation between the economic growth and energy consumption, the state regulative in the energy sector, the environmental impact of energy consumption etc.

learning outcomes
Students acquire a knowledge and skills related to energy planning by using statistical and econometric methods and by applying the phenomenological models, as well as related to methods for providing the basis for planning procedures, such as analyses and preparation of energy balances, prediction of indicators of energy consumption, etc.

theoretical teaching
Macro energy systems, energy systems of Serbia and the World: energy balance of Serbia, energy flows and structure of energy consumption in Serbia and the World. Classification of energy carriers and indicators of energy consumption. Relation between economic growth and energy consumption. Specific and useful energy consumption. Energy efficiency. Energy audit. Rational energy consumption. Techno-economic methods for energy investment evaluations and measures for rational energy consumption. Renewable energy consumption and new energy sources/technologies. Processes and plants for energy accumulations. Methods for energy systems modelling. Energy planning and policy. Law regulative in energy sector. Environmental impact of energy consumption.

practical teaching
Macro energy systems balancing, prediction of energy, economic and technological indicators of energy consumption, optimization and usage of energy plants for electricity production, planning of energy needs, electricity production costs, optimization of dimensions and operational parameters of energy plants and equipment, measures for rational energy consumption, methods for economic evaluation of energy efficiency measures (the net present value method, the internal rate of return method and the pay back period).

prerequisite
Passed exams in Thermodynamics and one subject within the Module for Thermal Power Engineering.

learning resources
Handouts.

Ristic, M., General energetics, Faculty of Mechanical Engineering, Belgrade, 1981.

Personal computers.

Software for energy planning and economic evaluation of investments.

Internet presentations of International Energy Agency and World Energy Council.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 20
laboratory exercises: 0
calculation tasks: 10
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 10
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 65
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Kleinpeter, M., Energy Planning and Policy, John Wiley & Sons, New York, 1995.
Chateau, B., Lapillonne, B., Energy Demand: Facts and Trends, Springer-Verlag, New York, 1982.
Eastop, T.D., Croft, D.R., Energy Efficiency, Longman Scientific & Technical, Harlow, 1990.
Gottschalk, C.M., Industrial Energy Conservation, John Wiley & Sons, 1996.
Energy Policy, The International Journal, Elsevier.

Environmental Protection in Thermal Power Engineering

ID: MSc-1319
responsible/holder professor: Milivojević S. Sanja
teaching professor/s: Milivojević S. Sanja, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: oral
parent department: thermal power engineering

goals
The aims is acquiring academic knowledge about sources and characteristics of hazardous gases emission and other harmful influences in all phases of thermal power plants exploitation, about the environmental influence of harmful emission, about possible technical solutions, processes and equipment for the emission reduction, harmful waste storage, as well as about the importance of these activities for economic and social development.

learning outcomes
The students master their knowledge and skills in the field of environmental protection from the harmful emissions from the thermal power plants. Besides being acquainted with the sources of harmful emissions and methods and equipment for their reduction and storage, the students are trained to quantify harmful emissions and to estimate the technical, ecological and economical effects of current methods and measures for environmental protection.

theoretical teaching
The influence of thermal power plants on environment and harmful emissions, maximum allowed emissions, regulatory laws related to harmful emissions, international activities towards environment protection and reduction of green house gases emissions, technologies and plants for emission reductions from thermal power plants, such as dust removal from flue gases, flue gases desulphurization, NOx removal, carbon dioxide capture and storage. The influence of atmospheric conditions on emissions propagation and harmful matters dispersion, storage of solid combustion products, heat load to the environment from thermal power plants, current developments of thermal power plants efficiencies from the standpoint of emissions reductions.

practical teaching
Prediction of the harmful emissions during the operation of the thermal power plants, evaluation of conceptual design of plants for the harmful emissions reduction in accordance with the law regulation, ecological and economical effects of methods for emission reduction, criteria for chimney selection, analyses of wet and dry methods for flue gases desulfurization, analyses of plant accidental conditions on environmental pollution.

prerequisite
Passed exam in Thermodynamics.

learning resources
Course handouts. Instructions for seminar work. Vendors' technical documentation of plants for environmental protection at thermal power plants.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15

laboratory exercises: 0
calculation tasks: 0
seminar works: 10
project design: 0
consultations: 5
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 4
check and assessment of projects: 0
colloquium, with assessment: 8
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 20
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references

Salvato, J.A., Nemerow, N.L., Agardy, F.J., Environmental Enginering, Wiley, 2003.
Woodruf, E.B., Lammers, H.B., Lammers, T.F., Steam Plant Operation, McGraw-Hill, NewYork, 1998.
Beer, J.M., High efficiency electric power generation: The environmental role, Progress inEnergy and Combustion Science 33 (2007) 107–134.
Reference Document on Best Available Techniques (BAT) for Large Combustion Plants,European Commission, 2006, 2016.

Gas Turbines

ID: MSc-0300
responsible/holder professor: Petrović V. Milan
teaching professor/s: Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
1. The achievement of academic competence in the field of gas turbines and thermal power plant engineering.

2. Mastery of theoretical knowledge about how to transform heat into mechanical work of thermodynamic processes and equipment (gas turbines and gas turbine power plants).

3. The acquisition of practical skills for design and optimization of gas and gas turbine cycle.

4. Mastering the techniques of process modeling.

learning outcomes
1. Academic deep knowledge of the thermodynamic cycle and flows in gas turbines and gas turbine plants

2. The development of critical thinking about energy use, fuel efficiency and environmental preservation

3. The ability of calculate heat balance diagrams and main parameters of the gas turbine power plants.

4. Ability to use computer technology for modeling and calculations

theoretical teaching
Theoretical teaching is carried out through 10 teaching modules:

1. Thermodynamic basis of the gas turbines power plants. The basic thermodynamic cycles.

2. The basic and main thermodynamic parameters of the gas turbine plants.

3. The influence of basic parameters on the performance of the gas turbine plants. The choice of optimal parameters of the gas turbine plants.

4. Energy balance of the gas turbine plants. Improvements the thermodynamic gas turbine plants.

5. More complex cycles of gas turbine plants.

6. Combined gas and steam plant turbine. Gas turbine plants with gasification of coal.

7. The application of gas turbines in the energy and airplane propulsion.

8. The construction of gas turbines. Materials of gas turbines. Selection of temperature at the entrance to the gas turbine. Blade cooling and cooling problems.

9. Combustion chambers - functions and operating principles, performance. Types of combustion chambers. Fuel for gas turbines. Auxiliary equipment of gas turbine plants.

10. Operating characteristics of gas turbines - change mode. Regulation of gas turbines.

practical teaching
Practical training is carried out through:
Auditory exercises:
Basic principles. Historical development. Classification, properties and applications of gas turbines. The application of gas turbines for the propulsion of vehicles, ships rail.
Instructions for project 1: Calculation of the gas turbine thermal cycle (heat balance diagram) of the gas turbine plants.
Instructions for project 2: Calculation of the combined cycle with gas turbine and steam turbine (CCGT).
Project development:
Calculation of heat balance of the gas turbine power plant.
Calculation heat balance diagram of combined cycle with gas turbine and steam turbine.
Labs:
introduction in principles of operation and design of gas turbines in the Laboratory for steam and gas turbines

prerequisite
Passed exams in Thermodynamics and Fluid mechanics

learning resources
Petrovic, M.: Gas turbines and compressors, script, 2004.

Petrovic, M.: Gas turbines and compressors, introduction for exercises, 2004.

Petrovic, M. scripts and handouts for Gas turbines

Instructions for performing laboratory exercises

Software package for calculating of properties of combustion products

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 13
consultations: 0
discussion and workshop: 3
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 5
test/colloquium: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 25

references

Petrovic, M.: Gas turbines and compressors, script, 2004.
Stojanovic, Thermal Turbomachinery, Gradjevinska knjiga, belgrade, 1967.
Cohen, H., Rogers,G.F.C., Saravanamuttoo, H.I.H.: Gas turbine theory, Logman, 1997.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Boyce, M.: Gas turbine engineering hadbook, GPB, Boston 2002.

Nuclear Reactors

ID: MSc-0345
responsible/holder professor: Stevanović D. Vladimir
teaching professor/s: Milivojević S. Sanja, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
The aims of the subject are acquiring academic knowledge about processes and equipment for nuclear energy utilization, about neutron processes and fission, principles of nuclear reactors design, reactor core cooling, nuclear fuel characteristics, transport and storage of nuclear waste, nuclear reactors safety, nuclear accidents in Nuclear Power Plants Three Mile Island, Chernobyl and Fukushima, as well as current nuclear reactors developments.

learning outcomes
Students are able to design nuclear reactor core, determine the thermal and neutron characteristics of nuclear fuel, moderator and reactor coolant, define basic elements of nuclear power plant safety and determine basic technical, technological, ecological and economic conditions and boundaries for the application of nuclear energy.

theoretical teaching
Processes and equipment of nuclear energy plants. Characteristics of nuclear fuel, atomic and nuclear processes important for the nuclear reactors operation. design of nuclear reactor material structure and critical dimensions. Diffusion and thermalization of neutrons. Solving of reactor equation. Operating characteristics and safety of nuclear reactors and nuclear power plants. Feedback between nuclear and thermal processes in the nuclear reactor core. Cooling of the nuclear fuel elements, heat transport and boiling crises. Computer codes for thermal-hydraulic simulation and analyses. Overview of nuclear energy in the World and its current development. The roll of the nuclear energy in the energy sustainable development.

practical teaching
The students solve the problems related to nuclear reactors design and analyses of its operation conditions. The numerical experiments are performed with the computer simulations of nuclear reactor processes: calculation of the radioactive chain decay, neutron life cycle and reactor equation solving for various types of nuclear reactors, the model development and computer simulation of the loss-of-feedwater accident in a plant with the pressurized water reactor.

prerequisite
Passed exams in Physics, Thermodynamics, Numerical methods.

learning resources
Course handouts.

Ristic, M., et al. Modelling of transients in nuclear steam supply systems, Faculty of Mechanical Engineering, Belgrade, 1984.

Ristic, M., Nuclear Reactors, Faculty of Mechanical Engineering, Belgrade, 1969.

Computer equipment.

Software for numerical solving systems of differential equations.

Software for the design of nuclear reactor core.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Klimov, A., Nuclear Physics and Nuclear Reactors, Mir Publishers, Moscow, 1981.
Tong, L.S., Design Improvement for Light Water Reactors, Hemisphere, New York, 1988.
Knief, R.A., Nuclear Energy Technology, Hemisphere, 1981.
Foster, A., Wright, R.L., Basic Nuclear Engineering, Allyn and Bacon, Inc., Boston, 1977.

Skill Praxix M - TEN

ID: MSc-1206
responsible/holder professor: Petrović V. Milan
teaching professor/s: Banjac B. Milan, Petrović V. Milan, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: oral
parent department: thermal power engineering

goals
The aim of this course is to introduce students to the process of design and analysis of thermal power plants, processes and systems, power equipment manufacturing process, methods of calculation and analysis of mechanical and thermal loads of energy equipment, technological lines of production, quality control, organization of construction methods, maintenance schedules and technological systems at power plants, transportation, power equipment, modern methods of calculation.

learning outcomes
The successful completion of course students are introduced to: the appropriate energy processes, major and minor technological systems, the spatial distribution of equipment, methods, process analysis, measurement of process parameters, facilities management systems, etc.

theoretical teaching
Introduction. The role and importance of professional practice in thermal power engineering.

Basics of the measures of security and safety when using equipment and resources for work in general and particularly in the field of thermal energy.

Basic principles of thermal turbomachinery.

Fundamentals of thermal processes in power plants.

Steam turbine plants. Boiler installations. Auxiliary systems.

Organization of work in a power plant. Sectors and services.

Measurement and regulation equipment in thermal power.

Instructions for keeping a diary.

practical teaching
Organization of visits to factories and

• design and consulting organization in the field of energy,

• organizations that produce and maintain equipment,

• organizations that build and maintain power plants and power plants,

• power plants and other power plants,

where part of the practice are held in the Faculty of Mechanical Engineering in the laboratories of the Department for thermal power engineering.

In the laboratories of the Department for thermal students become familiar with the available equipment and measuring devices. In an independent work, students completing the technical report process with practice.

prerequisite
There are no preconditions

learning resources

Petrovic, M.: Steam turbines, script, 2004.

Petrovic, M.: Gas turbines and compressors, script, 2004.

Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004

Petrovic, M.: Scripts and handouts for Steam turbines

number of hours: 90

active teaching (theoretical): 0
lectures: 0
elaboration and examples (revision): 0

active teaching (practical): 80
auditory exercises: 2
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 78
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 10

assessment of knowledge (maximum number of points - 100)

feedback during course study: 70
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 70

references

Petrovic, M.: Steam turbines, script, 2004.
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgarde, 1987.
Stojanovic, Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Petrovic,, Gas turbine and turbocompressors, script, 2004.
Boyce, M.: Gas turbine engineering hadbook, GPB, Boston 2002.

Steam generators

ID: MSc-0129
responsible/holder professor: Stevanović D. Vladimir
teaching professor/s: Milivojević S. Sanja, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
The aims of the subject are acquiring academic knowledge about processes and equipment for steam generation in thermal power plants, building and mastering skills in scientific and engineering methods for the prediction, analyses and research of thermal-hydraulic processes in steam generators, as well as skills in methods for the design, safety analyses and diagnostics of the operational conditions of the steam generators.

learning outcomes
Mastering the course the students are able to simulate and analyze processes, design equipment and prescribe operational conditions in steam generators by applying the modern scientific and engineering methods for various conditions of exploitation. Also, the application of acquired knowledge and skills in every stage of design, manufacture and exploitation provide the safe, reliable and economically and energetically efficient operation of steam generators.

theoretical teaching
Design of steam generators; thermal-hydraulic parameters of vapour and liquid two-phase flow: static, flow and thermodynamic quality, vapour void fraction, two-phase mixture density, superficial velocity, two-phase flow mass flux, slip factor, drift velocity, etc.; heat transfer mechanisms in convective heating, boiling and superheating of working fluids or heat carriers; the critical heat flux; pressure change in two-phase flow; modelling of thermal-hydraulic processes in steam generators: the homogeneous model, the slip model, the two-fluid and multi-fluid models of two-phase mixture flows; numerical methods for solving the thermal-hydraulic models of two-phase flow; computer simulations of operational conditions of steam generators; pressure waves propagation and dynamic loads of pipelines in transient conditions; the chocked flow; the condensation induced water hammer; two-phase flow instabilities; steam separation.

practical teaching
Prediction of two-phase flow parameters for various geometry and boundary conditions. Calculation of two-phase flow pressure drop. Calculation of mass, momentum and energy balances in evaporating channel. Prediction of boiling and dry-out boundaries in evaporating channels. Calculation of thermal-hydraulic parameters in circulation loops in steam generators. A development of one-phase and two-phase flow models for the simulation and analyses of two-phase flow in evaporating channels: mass, momentum and energy balance equations, closure laws for interfacial transport processes. Numerical methods fro two-phase flow models solving. Computer simulations of circulation loops in steam generators at full and partial loads. Modelling and computer simulation of pressure transients in pressurizers filled with vapour and liquid phases.

prerequisite
Passed exams in Thermodynamics, Fluid mechanics and Numerical methods.

learning resources
Subject handouts.

Stevanović, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, Monograph, Faculty of Mechanical Engineering, Belgrade, 2006, ISBN 86-7083-569-X.

Personal computers.

Software for the solving of systems of differential equations.

Software for the simulation and analyses of pressure transients in pipeline networks and pressurizers.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 5
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 30

references
Ishigai, S., Steam Power Engineering - Thermal and Hydraulic Design Principles, Cambridge University Press, 2010.
Reznikov, M.I., Lipov, Yu.M., Steam Boilers of Thermal Power Plants, Mir Publishers, Moscow, 1985.
Whalley, P.B., Two-Phase Flow and Heat Transfer, Oxford Science Publications, Oxford, 1996.
Delhaye, J.M., Thermohydraulics of Two-Phase Systems for Industrial Design and Nuclear Engineering, Hemisphere, 1981.
Stevanović, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, Monograph, Faculty of Mechanical Engineering, Belgrade, 2006, ISBN 86-7083-569-X.

Steam Turbines 1

ID: MSc-0274
responsible/holder professor: Petrović V. Milan
teaching professor/s: Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
1. The achievement of academic competence in the field of steam turbines and thermal power engineering.

2. The achievement of theoretical knowledge about how to transform heat into mechanical work learning thermodynamic processes and equipment (steam turbine and steam turbine power plants).

3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam turbines.

4. The achievement of the techniques of process modeling.

5. Mastering the methods of experimental work in thermal power engineering.

learning outcomes
On completion of this programme, it is expected that student will be able to:

• identify the thermodynamic cycle parameters affecting the quality of the installation and optimization of thermodynamic cycle steam turbine,

• perform calculation of of the heat balance diagram, the steam expansion process in the turbine, the process in the condenser and feedwater heater,

• determine the main thermodynamic parameters of steam power plant that define the quality of plant operation

• set the control boundary and make the balance of the turbine plant and the whole power plant according to the first and second law of thermodynamics,

• perform calculation of main gasodynamic parameters (row efficiceny, loss coefficient , deviation and exit flow angle) of the steam turrbine cascade based on geometric and operating parameters

• apply one-dimensional theory of compressible fluid flow in the one-dimensional turbine stage design,

• identify and select stage between action and reaction type,

• professional and accurately communicate using the terminology of the respective product areas.

theoretical teaching
Theoretical teaching is carried out through 10 teaching modules:

1) Thermodynamic background of the steam turbines and steam turbine cycles. Thermodynamic improvements, increase of live steam temperature and pressure, condensation, and decrease of the condensation pressure.

2) Reheat. Regenerative feed water heating. The basic thermodynamic cycles and heat balance diagrams.

3) Steam turbine power plant -the 1st and 2nd law of thermodynamics.

4) The fluid dynamics background of steam turbines, gas-dynamic processes in steam turbines.

5) Cascades of the steam turbine. Geometry and operating parameters. The main gas-dynamic parameters of the steam turbines cascades.

6) The aerodynamic losses in the cascades.

7) 1D theory of elementary stages of steam turbines. Euler equation for the turbine. Efficiency of the stage.

8) Axial elementary impuls stage.

9) Axial elementary reaction stage of Parsons type.

10) Internal efficiency of the stage. Internal losses. Determination of main dimensions of stage.

practical teaching
Practical teaching is carried out through:

Auditory exercises: basic principles. Historical development. Classification and application of steam turbines. Explanation of the heat balance diagrams and the functioning of components of the steam turbine plants. Instructions for calculation of the heat balance diagram and the main thermodynamic parameters of the steam turbine plants. Instruction to create an energy and exergy balance of the steam turbine plant according to the 1st and the 2nd law of thermodynamics.

Labs: Experimental determination of the specific steam consumption of steam turbines at the Laboratory of Mechanical Engineering.

Project design: Calculation of the heat balance diagram, the main thermodynamic parameters and the balance of the steam turbine plant.

prerequisite
Passed exams in Thermodynamics and Fluid mechanics

learning resources
Petrovic, M.: Steam turbines, script, 2004.

Vasiljevic, N.: Steam turbines Faculty of Mechanical engineering, Belgarde, 1987.

Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004

Petrovic, M.: Scripts and handouts for Steam turbines

Instructions for performing laboratory exercises

Software package for calculating of properties of steam and water.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 9
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 13
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 25

references
Petrovic, M.: Steam turbines, script, 2004.
Stojanovic, Themal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgarde, 1987.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Leyzerovich, A.: Steam Turbines for Modern Fossil-Fuel Power Plants, CRC Press, 2008

Steam Turbines 2

ID: MSc-0174
responsible/holder professor: Petrović V. Milan
teaching professor/s: Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
1. The achievement of academic competence in the field of steam turbines and thermal power engineering.

2. The achievement of theoretical knowledge about how to transform heat into mechanical work learning thermodynamic processes and equipment (steam turbine and steam turbine power plants).

3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam turbines.

4. The achievement of the techniques of process modeling.

5. Mastering the methods of experimental work in thermal power engineering.

learning outcomes
On completion of this programme, it is expected that student will be able to:

• optimization calculation of the turbine stage and select dimensionless stage parameters;

• selects the type of turbine cascade, construct airfoils and calculated the corresponding losses,

• set up a concept of the turbine relating to number of cylinars and the number of flow

• determine number of the turbine stages,

• conduct a detailed calculation of a turbine stages determining the main dimensions of the steam turbine,

• applty the theory of 3D flow for the turbine stages,

• perform basic design of steam turbine based on the carried calculations,

• knows the problems of operation and design of the last steam turbine stage,

• analysis of the problems of strength of the various elements of steam turbines

• analye the main problems vibration structural elements of the steam turbine,

• select the methods of regulating and analyze the opeartion of steam turbine at off design conditions.

theoretical teaching
Theoretical teaching is carried out through 10 teaching modules:

1) 3D flow in steam turbines stages.

2) 3D flow in stages with large length blades.

3) Design of steam turbines.

4) Multistage steam turbines.

5) Blades - design, stress, constant strain blades, vibration and erosion.

6) Steam turbine rotors - construction, stress, vibration.

7) Housing of steam turbines - design, stress, deformation and thermal dilation. Commissioning of steam turbines in operation, heating, cooling.

8) Steam turbine bearings - design, lubrication. Labyrinth seals. Protection components of steam turbines.

9) Operating characteristics of steam turbines, consumption cone.

10) Regulation of steam turbines, thermodynamic and functional problems.

practical teaching
Practical training is carried out through:

Auditory exercises:

Instructions for the project. Calculation and construction of steam turbines. Selection of blade profiles. Design turbine of high, medium and low pressure. Calculation of the number of stages. Calculation of the turbine last stage.

Labs:

Measurement of vibration of the rotor and the frequency of free oscillations of the steam turbine blades in the Laboratory of Mechanical Engineering.

Project development:

Calculation and design of steam turbines

Excursion:

Visit one thermal power plant in Serbia

prerequisite
Passed exams in Thermodynamics and Fluid mechanics

learning resources
Petrovic, M.: Steam turbines, script, 2004.

Vasiljevic, N.: Steam turbines Faculty of Mechanical engineering, Belgarde, 1987.

Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004

Petrovic, M.: Scripts and handouts for Steam turbines

Instructions for performing laboratory exercises

Software package for calculating of properties of steam and water.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 12
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 25

references
Petrovic, M.: Steam turbines, script, 2004.
Stojanovic, Themal Turbomachinery, Gradjevinska knjiga, belgrade, 1967.
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgarde, 1987.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Leyzerovich, A.: Steam Turbines for Modern Fossil-Fuel Power Plants, CRC Press, 2008

Steam Turbines 3

ID: MSc-1262
responsible/holder professor: Petrović V. Milan
teaching professor/s: Banjac B. Milan, Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal power engineering

goals
The aim of the course is to provide a base of knowledge in specific applications of thermal power plants for combined production of electricity and heat in the industrial and utility of thermal energy. In scope of the development of modern thermal power generation, the applications of combined heat and power production is of growing importance due to the high primary energy savings. Exercise program consists in the development of computational tasks for modes of combined heat and power production based on the implementation of certain acquired practical knowledge of the course program.

learning outcomes
On completion of this programme, it is expected that student will be able to:

• select type of the steam turbine for production of electricity in industry,

• select tuype of the steam turbine for combined production of power and heat (CHP)

• conduct the feasibility study of introducing combined production of power and heat comapring to the separate production,

• perform thermodynamic calculation of backpressure turbine and condensing turbine for combined production of power and heat in nominal and off-design mode,

• calculation of operation of turbine stage at off-design loads,

• select a gas turbine for combined production of power and heat

• select organic Rankin cycle for use of waste heat.

theoretical teaching
The development and significance of combined energy production in the world. Thermodynamic effects and energy benefits of combined energy production compared to separate production of identical amount energy in power plants and heating plants. Types of thermal power plants for combined production of energy: steam power plants, gas power plants and combined gas-steam power plants. Factors influencing the choice of the type of thermal power plants for combined production of energy. Diagrams of heat consumption. The main thermodynamic parameters of combined energy. The influence of distance of consumer on choice of parameters and primary energy savings in the combined production. Types of steam turbine plants for combined energy. Steam power plants for combined production of energy. Methods of load regulation and operating flow characteristics or steam turbines. Diagrams of regimes for combined energy production.

practical teaching
Includes three tasks in the field of combined energy production. The first task related to condensing steam turbine power plant with regulated steam extraction. The second task is related combined heat and power production with or without bypassing high pressure heaters in condensing steam turbine power plant with regulated steam extraction. The third problem relates to the definition of the diagram requires thermal heating consumption diagram and quality control requirements in the surface heat exchanger in substation of centralized heating system.

prerequisite
exams of steam and gas turbines.

learning resources
1. Kostyuk A., Frolov V.: Steam and Gas Turbines, Energoatomizdat, Moscow, 1988.-KSJ

2. Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ

3. Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.-KDA

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
consultations: 4
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 5
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 5
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 0

references
Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988
Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.
Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.

Themal Power Plants 2

ID: MSc-1261
responsible/holder professor: Petrović V. Milan
teaching professor/s: Banjac B. Milan, Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal power engineering

goals
The aim of the course is to provide a knowledge base in the field of planning, design, contracting, acceptance tests, operation and maintenance of thermal power plants. Exercise program consists of making of a shortened power plant conceptual design based on the implementation of certain acquired practical knowledge of the course program.

learning outcomes
On completion of this programme, it is expected that student will be able to:

• make preliminary design of the thermal power plant with steam and gas turbines,

• analyze and choose the location for the construction of thermal power plants,

• choose the most suitable thermal power technology for a given type of use,

• perform calculation of the working conditions and capacity of individual system and components of the thermal power plants

• define the concept and disposition projected plants

• carry out measurements of the most important operating parameters (pressure, temperature and flow) on the steam turbine plant

• conduct tests of steam turbine plant to determine the thermal efficiency of the steam turbine plan as well as the efficiency of the steam turbine,

• analyze test data of steam turbine plant and apply the appropriate correction to translate the real working conditions to the desingn conditions,

• calculate production price of electricity and heat in combined energy production and economic feasibility parameters determine.

theoretical teaching
The main phases of the design of thermal power plants. Criteria for selection of the type and location of the power plant. The content of the preliminary design to the investment program. The general layout and composition of the thermal power plant. Guidelines for contracting and procurement of equipment of thermal power plants. Acceptance and operational testing of the thermal power plant. Behavior of the thermal power plants in operation: start and stop modes. Maintenance and monitoring of the thermal power plants operating conditions: maintaining the protection and regulation, monitoring of the turbine, the turbine deposition and their removal, the importance of maintaining the quality of the water regime, condensing plants, regenerative heating system of main condensate and feedwater, turbine sealing system, etc. The importance of following of diagnostic operating conditions, cost control and the functional readiness of the power plant. Reliability and availability of power plant.

practical teaching
Making of a conceptual design of a power plant: selection of the power plants micro location, general concepts, choice disposition of all power plant parts, analysis of selection schemes and thermal parameters. The main mechanical unit: an analysis of selection schemes and thermal parameters, the

choice of boiler, selection of steam turbine plants. Calculation task consists in the development of computer programs for calculating the impact parameter deviations live steam on the cost of the steam turbine plant.

prerequisite
Course in Steam Turbines

learning resources
Written manusscript and textbooks:

1. Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988. - KCJ

2. Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ

3. Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.-KDA

4. Vasiljevic, N., Savic,B>, Sojakovic, M.: Investigation of optimal design and operating conditions of condensing part of steam power plants, Faculty of Mech. Engineering, Belgrade 1991.

5. Schroeder, K: Grosse Dampftkraftwerke, Springer Verlag, Berlin, 1962

6. CEGB: Modern Power Station Practice, Pergamon press, Oxford, 1971

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 0
calculation tasks: 4
seminar works: 0
project design: 20
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 3
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 30

references

Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988
Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.
Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.
Schroeder, K: Grosse Dampftkraftwerke, Springer Verlag, Berlin, 1962
CEGB: Modern Power Station Practice, Pergamon press, Oxford, 1971

Thermal Power Plants 1

ID: MSc-1260
responsible/holder professor: Petrović V. Milan
teaching professor/s: Banjac B. Milan, Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal power engineering

goals
Getting to know the procedures for the selection of the type, parameters and configuration of the thermal power plant according to demand of energy consumption, available sources of primary energy, energy and economic performancees and other important criteria. Also, learning on the performance and technological characteristics of individual technological systems in thermal power plants. Exercise program is based on the implementation of certain practical knowledge of the course program by solving of specific examples.

learning outcomes
On completion of this programme, it is expected that student will be able to

• identify different technological subsystems within the thermal power plant,

• projects technological scheme of thermal power plants with steam and gas turbines,

• conduct techno-economic analysis of the operation of thermal power plants, calculate the production price electricity and determine the economic feasibility parameters ,

• alculate and optimize the condenser plant,

• determine the necessary flow of cooling water ,

• perform calculation and optimization of feed water heater.

theoretical teaching
The influence of the main factors and criteria for the selection of the thermal power plant. The structure and characteristics of the final energy consumption. The choice of configuration and parameters of the thermal power plants: basic and main thermodynamic parameters for steam and gas power plants, thermodynamic improvments of steam and gas turbine power plants. Estimation of the cost of electrical energy production and the optimization criteria of the thermal power plants: the total costs of energy production, comparative cost factors as optimization criteria and indicators of economic viability. Power plant and a complex technological system. Technological scheme of thermal power plants. Technological scheme of the main system for the production of electricity that includes the start and stop function block.Other systems: fuel supply, drainage, transportation and disposal of ash and slag, condensation plant with a system for supplying cooling water, system for the control and management of steam plants.

practical teaching
Visits to power plant are planed to learn about the major technological power generation systems (steam turbine plant and boiler house) with the main auxiliary technological systems. Foresees a Three tasks related to the calculation of production costs and prices of unit of electricity, design of technological scheme of the main power plant cycle and the application of economic parameters to optimize the thermal power plant. Test of students knowledge is planed by 3 tests in theoretical fields, examination and evaluation of calculation tasks and report on the visit to power plant.

prerequisite
Passed exams in Thermodynamics and Fluid mechanics

learning resources
Written manusscript.

1. Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988. - KCJ

2. Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ

3. Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.-KDA

4. Vasiljevic, N., Savic,B>, Sojakovic, M.: Investigation of optimal design and operating conditions of condensing part of steam power plants, Faculty of Mech. Engineering, Belgrade 1991.

5. Schroeder, K: Grosse Dampftkraftwerke, Springer Verlag, Berlin, 1962

6. CEGB: Modern Power Station Practice, Pergamon press, Oxford, 1971

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 5
calculation tasks: 17
seminar works: 0
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 8
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 20
seminar works: 0
project design: 0
final exam: 50
requirements to take the exam (number of points): 0

references
Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988
Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.

Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.
Schroeder, K: Grosse Dampftkraftwerke, Springer Verlag, Berlin, 1962
CEGB: Modern Power Station Practice, Pergamon press, Oxford, 1971

Thermal Turbomachinery

ID: MSc-0337
responsible/holder professor: Petrović V. Milan
teaching professor/s: Banjac B. Milan, Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals

1. The achievement of academic competence in the field of steam and gas turbines and thermal power engineering.

2. The achievement of theoretical knowledge about how to transform heat into mechanical work learning thermodynamic processes and equipment (steam and gas turbines and thermal power plants).

3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam and gas turbines.

4. The achievement of the techniques of process modeling.

5. Mastering the methods of experimental work in thermal power engineering.

learning outcomes

1. Academic deep knowledge of the thermodynamic cycle and flows in steam and gas turbines and turbine plants

2. The development of critical thinking about energy use, fuel efficiency and environmental preservation

3. The ability of calculate heat balance diagrams and main parameters of the steam and gas turbine power plants.

4. Ability to use computer technology for modeling and calculations

theoretical teaching

1)Thermodynamic background of the steam turbines and steam turbine power plants. Thermodynamic improvements of the thermodynamic cycles.

2) Reheat. Regenerative feed water heating. The basic thermodynamic cycle.

3) Steam turbine power plant -the 1st and 2nd law of thermodynamics.

4) Cascades of the steam turbine. Geometry and operating parameters. The main aerodynamic parameters of the steam turbines cascades.

5) The aerodynamic losses in the cascades.

6) 1D theory of elementary stages of steam turbines. Euler equation for the turbine. Efficiency of the stage

7) Axial impulse stage. Axial reaction stage. Internal efficiency of the stage. Internal losses degrees.

8) Thermodynamic basis of the gas turbine plant. The basic thermodynamic cycle. The basic and main thermodynamic parameters of the gas block.

9) The influence of basic parameters on the performance of the gas turbine plant. The choice of optimal parameters of the gas turbine plant.

10) Balance of energy of the gas turbine plant. Possibilities to improve the thermodynamic gas turbine plant. More complex configurations of gas turbine plant. Combined gas and steam plant turbine.

practical teaching
Practical teaching is carried out through:

Auditory exercises: basic principles. Historical development. Classification and application of steam turbines. Explanation of the heat balance diagrams and the functioning of components of the steam turbine plants. Instructions for calculation of the heat balance diagram and the main thermodynamic parameters of the steam turbine plants. Instruction to create an energy balance of the steam turbine plant according to the 1st and the 2nd law of thermodynamics.

Labs: Experimental determination of the specific steam consumption of steam turbines at the Laboratory of Mechanical Engineering.

Project design: Calculation of the heat balance diagram, the main thermodynamic parameters and the balance of the steam turbine plant.

prerequisite
Passed exams in Thermodynamics and Fluid mechanics

learning resources
Petrovic, M.: Steam turbines, script, 2004.

Petrovic, M.: Gas turbines and compressors, script, 2004.

Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004

Petrovic, M.: Scripts and handouts for Steam turbines

Instructions for performing laboratory exercises

Software package for calculating of properties of steam and water.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 14
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 12
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 0
test, with assessment: 2
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 10

laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 25

references

Petrovic, M.: Steam turbines, script, 2004.
Stojanovic, Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgarde, 1987.
Petrovic,, Gas turbine and turbocompressors, script, 2004.
Boyce, M.: Gas turbine engineering hadbook, GPB, Boston 2002.

Turbocompressors

ID: MSc-0336
responsible/holder professor: Petrović V. Milan
teaching professor/s: Petrović V. Milan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
1. The achievement of academic competence in the field of compressors and thermal power plant engineering.
2. Mastery of theoretical knowledge about how to transform mechanical work into internal energy of fluid by learning of thermodynamic processes and equipment.
3. The acquisition of practical skills for design and optimization of turbocompressors.
4. Mastering the techniques of process modeling.

learning outcomes
On completion of this programme, it is expected that student will be able to:

• perform design of a multistage axial compressor writing own program code,
• select dimensionless parameters of compressor stages,
• apply one-dimensional theory of the compressor stage, determine the main dimensions of the stage, calculate efficiency and the stage operating parameters,
• apply the appropriate solutions of 3D flow and define 3D blade geometry of the compressor stage
• select the type of aero profile, calculate the aerodynamic losses and deviation
• define the meridian flow path of the entire machine
• apply different control modes for the turbocompressor
• analyse compressor behavior at off-design operating parameters.

theoretical teaching
1. Thermodynamic background of turbocompressors. Isothermal, isentropic, polytropic and real process. Isentropic efficiency and polytropic efficiency.
2. The aerodynamic background of turbocompressors.
3.Cascades of turbocompressors. Geometric and operating parameters of the cascades.
4.Main aerodynamic cascade parameters. Aerodynamic losses in compressor stages.
5.Theory of the cascade aerodynamic coefficients.
6.Mean-line theory of compressor stages. Energy balance, Euler equation.
7.Design factors of turbocompressors. Dimensionless velocity triangles. Dependence of the compression ratio from the operating parameters.
8.Dependence of efficiency of the normal stages of axial compressor from the cascade aerodynamic coefficients and from the stage operating parameters.
9. 3D flow in axial compressors stages. Optimal design factors. Determination of main dimensions of axial compressors.
10. The behavior of the compressors at variable loads. Regulation of turbocompressors.

practical teaching
Practical training is carried out through:

Auditory exercises:

Introduction. Energy conversion in the compressors. The types of compressors. Application areas.

Instructions for project 1: Calculation of main dimensions of axial compressors.

Instructions for project 2: Design of the compressors cascades.

Project development:

Calculation of main dimensions of axial compressors.

Calculation of compressors cascades.

Labs:

Learning the principles of operatin and desing of compressors in Laboratory of steam and gas turbines.

prerequisite
Passed exams in Thermodynamics and Fluid mechanics

learning resources
Petrovic, M.: Gas turbines and compressors, script, 2004.

Petrovic, M.: Gas turbines and compressors, introduction for exercises, 2004.

Petrovic, M. scripts and handouts for Gas turbines

Instructions for performing laboratory exercises

Software package for calculating of properties of air and combustion products

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 9
laboratory exercises: 4
calculation tasks: 0
seminar works: 0
project design: 17
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 1
check and assessment of seminar works: 0
check and assessment of projects: 7
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 50
requirements to take the exam (number of points): 25

references

Petrovic, M.: Gas turbines and compressors, script, 2004.
Stojanovic, Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Cohen, H., Rogers,G.F.C., Saravanamuttoo, H.I.H.: Gas turbine theory, Logman, 1997.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Boyce, M.: Gas turbine engineering hadbook, GPB, Boston 2002.

Two-Phase Flows with Phase Transition

ID: MSc-0325
responsible/holder professor: Stevanović D. Vladimir
teaching professor/s: Milivojević S. Sanja, Stevanović D. Vladimir
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal power engineering

goals
The aim is acquiring academic knowledge about two-phase flow patterns, mechanisms of transport processes in two-phase flows, intensity of evaporation and condensation and methods for two-phase flows simulation and analyses within design, safety analyses and prescription of operating conditions and parameters of energy plants.

learning outcomes
The students are trained to perform computer simulation and analyses of gas-liquid two-phase flows within design of energy plants, safety analyses, operating conditions diagnostics, defining of operating conditions, etc.

theoretical teaching
Two-phase flow patterns and related maps. Two-phase flow modeling by multi-fluid models and corresponding closure laws for interface transport processes. Mechanisms of pressure change in two-phase flow and prediction methods. The effect of flooding in counter-current gas-liquid flow. Pool boiling and convective boiling. The critical heat flux and prediction methods. Condensation of pure vapour and condensation in the presence of noncondensables. Sonic waves propagation in two-phase flow. The chocked two-phase flow. Numerical methods for the solving of two-phase flow models. Computation of two-phase flows in components of energy and process plants.

practical teaching
Prediction of two-phase flow parameters: static, flow and thermodynamic quality, void fraction, two-phase flow density, superficial velocity, slip factor, drift velocity, etc. Empirical correlations for the prediction of void fraction, slip factor and drift velocity. The influence of the pressure level on the two-phase flow parameters. Prediction of pressure change in two-phase flow. Development of multi-fluid models of two-phase flow: balance equations, closure laws and solving methods. Application of the multi-fluid two-phase flow model to energy and process equipment, such as: evaporating channel, condensation in a pipe, heat exchangers with phase transitions, evaporators, steam boilers with boiling around tubes in a bundle, evaporating tubes in steam boiler furnace, condensers, pressurizers, feedwater tanks, steam boiler drum, steam accumulator, pipelines, etc.

prerequisite
Passed exams in Thermodynamics, Fluid Mechanics and Numerical Methods.

learning resources
Course handouts.
Computer equipment.
Computer codes for thermal-hydraulic simulations of two-phase flows and pressure transients in pipelines, pressurized vessels, heat exchangers with boiling or condensation in tube bundles.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 15
calculation tasks: 0
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 5
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 5
test/colloquium: 35
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 30

references
Whalley, P.B., Two-Phase Flow and Heat Transfer, Oxford University Press, Oxford, 1996.
Wallis, G.B., One-Dimensional Two-Phase Flow, McGraw-Hill, New York, 1969.
Clift, R., Grace, J.R., Weber, M.E., Bubbles, Drops and Particles, Academic Press, New York, 1978.
Delhaye, J.M., Giot, M., Rietmuller, M.L., Thermalhydraulics of Two-Phase Systems for Industrial Design and Nuclear Engineering, McGraw-Hill, 1981.
Stevanovic, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, University of Belgrade, Faculty of Mechanical Engineering, 2006.

THERMAL SCIENCE ENGINEERING

Air Conditioning Systems

ID: MSc-1258
responsible/holder professor: Todorović N. Maja
teaching professor/s: Sretenović Dobrić A. Aleksandra, Todorović N. Maja
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal science engineering

goals
Getting knowledge and skills in air conditioning - various central air conditioning systems; mastering methods for calculating air ducts, choosing elements for intake and extract of air, and using those methods in air conditioning project design.

learning outcomes
Upon successful completion of the course, students should be able to:

• Select the appropriate elements for supply air inlet in the air-conditioned room in order to achieve optimal air distribution in space

• Apply of different methods for the calculation of pressure drop in air ducts

• Explain the basic features central air conditioning systems (all air and air to water systems)

• Apply measures to increase energy efficiency of the air conditioning systems

• Estimate of the advantages and disadvantages of different systems for ventilation and air conditioning

• Apply their knowledge to solving practical problems in air conditioning development, design and installation

• Be efficient in team work

theoretical teaching
Air distributing elements; duct calculation methods; air distribution; airflow range; air inlet and extract position; air conditioning systems - classification; central single-duct low pressure system with constant air volume, zone air conditioning systems; high pressure air conditioning systems: with constant and variable airflow rate; air to water air conditioning systems; induction unit; two pipes systems change over and no change over; three-pipe and four-pipe systems; hydronic systems with fan coil units; combination with ventilating systems, local air conditioning systems; compact and split systems; energy efficiency of ventilation and air conditioning systems.

practical teaching
Auditory is composed of more sections, in order to complete project design. Design and regulating air conditioning systems, calculating energy consumption and using waste heat. Laboratory consists of measuring airflow in ducts and distributive elements, regulating air conditioning systems, measuring airflow range and intermediate operating mode. Visit to Thermal science exhibition in HVAC congress or to factory for air conditioning equipment is planned.

prerequisite
In order to attend subject it is required to pass the exam: Air Conditioning Fundamentals.

learning resources
B. Todorovic, Air conditioning; SMEITS, Belgrade, 2009.

M. Todorovic, A. Sretenovic: Handouts

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 21

references
ASHRAE Handbook of Fundamentals, Atlanta, Georgia, 2009
Recknagel, Sprenger, Schramek, Čeperković: Heating and Air Conditioning, Interklima, Vrnjačka Banja, 2012

Air-conditioning Fundamentals

ID: MSc-1257
responsible/holder professor: Todorović N. Maja
teaching professor/s: Sretenović Dobrić A. Aleksandra, Todorović N. Maja
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal science engineering

goals
Getting knowledge in Air Conditioning - thermal comfort, heat gain and cooling load, air handling unit and its elements, mastering methods for calculating cooling loads for non-stationary conditions of heat transfer and using those methods in air conditioning project design.

learning outcomes
Upon successful completion of the course, students should be able to:

• Understand influence of indoor thermal conditions on human thermal comfort

• Identified the process of unsteady heat transfer through the building envelope and inside air conditioned space

• Perform cooling load calculation for air conditioned buildings

• Select the appropriate amount of air for airconditioning system

• Carry out the selection of air handling unit elements heaters, coolers, humidifiers)

• Compare the characteristics of different systems for air filtration

theoretical teaching
Defining air conditioning; thermal ambiance conditions; thermal comfort in closed spaces; thermal regulation; meteorology and climate; Solar constant; atmosphere clearance; radiation on horizontal and vertical surfaces; outside and inside heat sources; heat transfer through single-layer and multiple-layer walls in non-stationary conditions of heat transfer; heat gains from solar radiation through window; heat storage factors; protection from solar radiation; shading effect on cooling load; heat gains from internal sources; calculation air flow rate for air conditioning; air treatment in air handling unit; air handling unit and its elements; heating and cooling coil; heat output control of heating and cooling coil; spraying chamber; evaporator; filtration; filter efficiency.

practical teaching
Auditory part consists of more sections: basic and complex processes in

Molier h-x diagram, calculating cooling load from inside and outside heat sources, calculating airflow rate for air conditioning, defining air parameters in summer and winter operating mode, in order to independently complete project assignment. Laboratory exercise is demonstrative - air handling unit and its elements, air conditioning accessoris. Visit to Technical fair or factory for air conditioning equipment is planned.

prerequisite
In order to attend this subject, it is needed to pass exams: Thermodynamic M and Fluid mechanics M.

learning resources
M. Todorovic, A. Sretenovic: Handouts

B.Todorovic: Air conditioning, SMEITS, Belgrade, 2009.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 21

references
ASHRAE Handbook of Fundamentals, Atlanta, Georgia, 2009
Recknagel, Sprenger, Schramek, Čeperković: Heating and Air-conditioning, Interklima, Vrnjačka Banja, 2002

Building energy certification

ID: MSc-1254
responsible/holder professor: Bajc S. Tamara
teaching professor/s: Bajc S. Tamara, Todorović N. Maja
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal science engineering

goals
Acquiring knowledge and skills in the field of energy certification of buildings - the concept of energy building certificate, building energy consumption, energy needs and significant parameters; comfort conditions and design parameters, central heating and air conditioning systems, energy sources, final and primary energy, domestic hot water systems; optimization of HVAC systems and the application of passive techniques, methodology of calculation of indicators, classification of buildings by type and energy codes; elaboration of energy efficiency, energy certificate.

learning outcomes
Students acquire specific skills and knowledge in the field of energy certification of buildings; known methods for the calculation of indicators to determine the energy code of the building and can be applied in practice. Connects the basic knowledge and applies them to the elaboration of energy efficiency of the building.

theoretical teaching
The concept of energy building certificate, Energy Performance of Buildings Directive – main objectives; Legislative in the Republic of Serbia; building energy consumption, energy needs and significant parameters; comfort conditions and design parameters, central heating and air conditioning systems, energy sources, final and primary energy, domestic hot water systems; optimization of HVAC systems and the application of passive techniques, application of renewable energy sources, methodology of calculation of indicators, classification of buildings by type and energy codes; measures for energy efficiency improvement; energy audit, elaborate of building energy efficiency, building energy certificate.

practical teaching
Practical skills consist of parts: Example of calculation of thermal properties of the building envelope elements - calculation of the coefficient of thermal conductivity, specific transmission and ventilation losses, building shape factor, determination of design conditions and technical systems' schedules of use, determining energy needs and indicators that define the energy code; application measures to improve energy efficiency of buildings - individual measures and measure sets improvement, financial analysis. Individual Project task – Building energy efficiency elaborate on the example of residential building.

prerequisite
Without conditions.

learning resources
1. Todorović M., Ristanović M., Efficiant energy usage in buildings, University of Belgrade, Belgrade, Serbia, 2015.
2. Todorović M., Energy certification of buildings – handouts
3. ***, Rulebook on energy efficiency of buildings, Official Gazette of Republic of Serbia No. 61/2011
4. ***, Rulebook on conditions, content and manner of issuing energy performance certificate of buildings, Official Gazette of Republic of Serbia No. 69/2012

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 0

references
Todorović M., Ristanović M., Efficiant energy usage in buildings, University of Belgrade, Belgrade, Serbia, 2015.
Todorović M., Energy certification of buildings – handouts
***, Rulebook on energy efficiency of buildings, Official Gazette of Republic of Serbia No. 61/2011
***, Rulebook on conditions, content and manner of issuing energy performance certificate of buildings, Official Gazette of Republic of Serbia No. 69/2012

Central Heating Systems

ID: MSc-1256
responsible/holder professor: Sretenović A. Aleksandra
teaching professor/s: Bajc S. Tamara, Sretenović Dobrić A. Aleksandra
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal science engineering

goals
Acquiring knowledge and skills in the field of central heating - hot water two-pipe systems with natural and forced circulation of hot water, hot water one-pipe systems, steam heating system of low pressure, air heating, panel heating, district heating, solar systems, mastering the methods for calculation of pipe network.

learning outcomes
Students acquire specific skills and knowledge of central heating systems: knowledge of different heating systems, known methods of calculation of central heating systems and can apply them in practice. Connects basic knowledge and apply it to solve concrete problems in the technique of heating.

theoretical teaching
Two-pipe hot water central heating pump systems, pipe heating system; correction of surface heaters, heating steam low pressure, upper and lower divorce; Steam traps, condensate return to boiler; calculation of pipe networks, heat transfer by radiation; panel heating systems, heat transfer from the budget tube, through multi-layered plate, the surrounding air, underfloor heating, air heating, ventilation chamber and its components, industrial ventilation, remote distribution of heat; characteristics of district heating, heat transport distance; substation for direct and indirect connection; heating sliding diagrams, renewable energy sources, active and passive use of solar energy and geothermal energy.

practical teaching
Auditory exercises consist of parts: pipe sizing for two-pipe hot-water network system with natural and forced circulation of water in the system and facilities 90/70oC to prepare and distribute hot water, and to individual work of reference. Lab exercise - testing thermal properties of heaters; temperature impact on the heat output of radiators; influence of the flow rate to heat output of radiators; behavior of heaters in non-stationary conditions (visit the exhibition of thermal engineering in the Congress of HVAC or visit the factory).

prerequisite
In order for a student attending the subject must have passed the exams in the subject:

Thermodynamics B and Heating technique Fundamentals

learning resources
Handouts - M. Todorović, A. Sretenović

B. Todorović - Central Heating Systems Design - Faculty of Mechanical engineering, Belgrade, 2009.

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5
calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 0

references

B. Todorović - Central Heating Systems Design - Faculty of Mechanical engineering, Belgrade, 2009.

Heat Pumps

ID: MSc-1120
responsible/holder professor: Milovančević M. Uroš
teaching professor/s: Milovančević M. Uroš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal science engineering

goals
Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

learning outcomes
Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

theoretical teaching
Characteristics of heat pumps: Systematization of thermal systems performing refrigeration cycles, The criteria for evaluation of thermodynamic quality of refrigeration cycles, Heat sources for heat pumps, (atmospheric air, surface water, groundwater and soil, geothermal energy, heat accumulators, solar plate collectors), Thermodynamic improvement of refrigeration cycles; Sorption refrigeration systems; Properties of refrigerant-absorbent mixtures: Basic steady-flow processes with binary mixtures; Basic vapour absorption refrigeration system, (VARS), Steady-flow analysis of the VARS, Maximum COP of ideal absorption refrigeration system, Comparison between compression and absorption refrigeration systems.

practical teaching
Auditory training: systematization of thermal systems performing refrigeration cycles, predicting of heat pumps performaнсes, mass and heat balance of drying processing, determination of characteristics of the heat pump elements, (compressor, condenser,evaporator), binary mixtures, the basic operations with binary mixtures, thermodynamic calculation of single effect VARS Laboratory exercise: demonstration of heat pumps for air conditioning system of a hotel building; Design project of heat pump system: work in groups of 5 students (for a particular object and refrigerant), calculation and selection of elements of heat pump, Analysis of complete vapour compression heat pump plant.

prerequisite
Necessary passed the test: Refrigeration Equipment, Refrigeration Systems

learning resources
1. Textbook: M. Markoski: Refrigeration, Mechanical Engineering, 2006,

2. Handouts which are available in advance for each week of classes

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 5

calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 21

references

Power steam boiler 1

ID: MSc-1116
responsible/holder professor: Stupar M. Goran
teaching professor/s: Stupar M. Goran
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal science engineering

goals
Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

learning outcomes
After successfully completing the course, the students will be able to:

• Calculate the material balance of the combustion process and the enthalpies of combustion products for solid fuels.

• Choose the excess air and apply flue gases recirculation.

• Get to know more about the structure of the irradiated and convective evaporator.

• Acquainted with the main superheater types and temperature control systems of a superheated vapor.

• Acquainted with the basic types of water heaters and air heaters.

• Calculate the heat balance of the steam boiler and its heat surfaces.

theoretical teaching
Worikng principle of a steam boiler and definitions of basic concepts; Fuels for steam boilers; Combustion material balance; Excess air; Flue gases enthalpy; Steam boiler heat balance, losses and efficiency; Steam boiler furnace; Steam boiler evaporators with natural and forced circulation loop; Half-radiation and convection evaporators; Radiation, half-radiation and convection superheaters; Reheaters; Different types of water heaters; Recuperative air heaters and regenerative air heaters.

practical teaching
Auditory exercises consist from demonstration exercises(classification of boilers; steam boiler construction; main and auxiliary devices and equipment); Working project - coal combustion material balance (coal calorific value, theoretical air volume for combustion , theoretical flue gas volume,

flue gases enthalpy diagram as a function of temperature and excess air); worikng principle of a industrial steam boiler; wetermining the losses, efficiency and fuel consumption of the given steam boiler; furnace dimensioning; heat and material balance of steam boiler heating surfaces.

prerequisite
Necessary condition: Bachelor's degree.

learning resources
Books: Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); handouts which will be at student's disposal a week in advance.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 10
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 30

references
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian)

Refrigeration Equipment

ID: MSc-1114
responsible/holder professor: Milovančević M. Uroš
teaching professor/s: Milovančević M. Uroš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal science engineering

goals
Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

learning outcomes
Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

theoretical teaching
Refrigeration compressors (systematization, application); Reciprocating refrigeration compressors: basic elements, basic parameters of operation, operating characteristics (performance) of reciprocating refrigeration compressors, processes in an Ideal and actual compressor, volumetric efficiency, Actual compression process, Capacity control of reciprocating compressors); Rotary refrigeration compressors, twin screw compressors; Auxiliary equipment and refrigeration pipelines, Condensers: classification of condensers, analysis of condensers; Evaporators: classification, direct expansion fin-and-tube type evaporators, flooded evaporators, evaporator defrosting; Expansion devices: thermostatic expansion valve.

practical teaching
Auditory training: A survey of the application area of certain types of compressors; Volumetric efficiency calculation; The compressor displacement calculation; Capacity control of reciprocating compressors; Design of rotary screw compressors; Compressor performance curves; Calculation of refrigeration load of condensers, Calculation of piping, insulation, safety valves and elements of automation. Laboratory exercise: demonstration of cooling installation in an industrial plant; Design project of refrigeration system: work in groups of 5 students (for a particular object and refrigerant), calculation and selection of elements refrigeration plants.

prerequisite
Required exams passed: thermodynamics, the basics of refrigeration

learning resources
1. Textbook: M. Markoski: Refrigeration, Mechanical Engineering, 2006,

2. Handouts which are available in advance for each week of classes

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 10
> laboratory exercises: 5

calculation tasks: 0
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 0

references

Refrigeration in Food Technologies

ID: MSc-1115
responsible/holder professor: Milovančević M. Uroš
teaching professor/s: Milovančević M. Uroš, Milovančević M. Uroš, Milovančević M. Uroš, Milovančević M. Uroš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal science engineering

goals
Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

learning outcomes
Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

theoretical teaching
Natural and artificial refrigeration, Application of refrigeration, Vapour compression refrigeration systems, The Carnot vapour compression refrigeration cycle, Improvement of vapour compression cycle, (subcooling, multistage throttling, multistage compression with intercooling), Standard vapour compression refrigeration plants, Refrigerants, refrigerant selection criteria; Designation of refrigerants; Reciprocating refrigeration compressors: Бasic elements, basic parameters of operation, operating characteristics (performance) of reciprocating refrigeration compressors; Condensers: classification of condensers; Evaporators: classification, evaporator defrosting; Cooling and quick freezing of food products

practical teaching
Auditory training: Moist air, thermodynamic properties of moist air, Mollier's "h-x" diagram, Important psychrometric processes, thermal insulation, selection of insulation materials, the diffusion of water vapor through thermal insulation layer, vapour barrier, calculation of refrigeration load, thermodynamic analyses of refrigeration cycle, Basic calculation for sizing of compressors, condensers and evaporators, process systems for quick freezing and storage of food products; Laboratory Exercise: Demonstration of refrigeration devices in industrial plants; Design project of refrigeration system: work in groups of 5 students (for a particular object and refrigerant), calculation of a refrigeration plant.

prerequisite
Required exams passed: Thermodynamics B; Desirable passed exam: Fluid Mechanics B

learning resources
1. Textbook: M. Markoski: Refrigeration, Mechanical Engineering, 2006,

2. Handouts which are available in advance for each week of classes

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 15
laboratory exercises: 3
calculation tasks: 0
seminar works: 0
project design: 12
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 45
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 15
final exam: 30
requirements to take the exam (number of points): 21

references

Refrigeration Systems

ID: MSc-1117
responsible/holder professor: Milovančević M. Uroš
teaching professor/s: Milovančević M. Uroš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: thermal science engineering

goals
Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

learning outcomes
Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

theoretical teaching
Thermodynamic basis: Moist air, thermodynamic properties of moist air, Mollier's "h-x"diagram, Important psychometric processes, Dalton's and Lewis's Law ofevaporation, Wet bulb temperature of moist air, Evaporation heat transfer calculation, Merkel's coefficient; Heat exchangers: NTU method, Heat exchanger characteristics; Characteristics of compressors; Condensers: Sizing of air-cooled, water-cooled and evaporative condensers; Evaporators: the process of refrigerant boiling, the processes on the cooled fluid side, Sizing of air cooling evaporators, Characteristics of evaporators; Analysis of complete vapour compression refrigeration systems.

practical teaching
Auditory training: Psychometric processes, Evaporation heat transfer; prediction of the compressor characteristic, sizing of condensers (air-cooled, water-cooled and evaporative), sizing of evaporators, evaporator characteristic calculation; Analysis of complete vapour compression refrigeration systems; Laboratory exercise: demonstration of the installation in an industrial refrigeration plant; Design project of refrigeration system: work in groups of 5 students (for a particular object and refrigerant), calculation and selection of elements of refrigeration plants, PI diagram of refrigeration plant.

prerequisite
Required exams passed: Refrigeration Equipment

learning resources
1. Textbook: M. Markoski: Refrigeration, Mechanical Engineering, 2006,

2. Handouts which are available in advance for each week of classes

number of hours: 75

> **active teaching (theoretical):** 30
> lectures: 20
> elaboration and examples (revision): 10
>
> **active teaching (practical):** 30
> auditory exercises: 10
> laboratory exercises: 5
> calculation tasks: 0
> seminar works: 0

project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 20
final exam: 50
requirements to take the exam (number of points): 21

references

Skill Praxis M - TTA

ID: MSc-1255
responsible/holder professor: Bajc S. Tamara
teaching professor/s: Bajc S. Tamara, Todorović N. Maja
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: thermal science engineering

goals
Practical experience and student learning in the environment in which the student will realize his professional career.

Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineer in such a business system.

learning outcomes
Students get practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, in the context of his future professional competence. Students are establishing the personal contacts and acquaintances that will be able to use during studies or entering into future employment.

theoretical teaching
There are not theoretical classes.

practical teaching
Practical work involves work in organizations that perform various activities in scope of mechanical engineering. Selection of thematic areas, commercial or research organizations is carried out in consultation with the concerned teacher. In general, a student can perform the professional practice in manufacturing organizations, design and consulting organizations, organizations engaged in mechanical equipment maintenance, and public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice also can be done abroad. During practice, students must keep a daybook in which enters a description of the performed tasks, the conclusions and observations. After the practice in company is finished, a report must be delivered and defended in front of the subject teacher. The report is submitted in the form of the daybook.

prerequisite
Without conditions.

learning resources
Literature recomended by professor and documents obtained by the expert from the organization where the practice is done.

number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 89
> auditory exercises: 0
> laboratory exercises: 80
> calculation tasks: 0

seminar works: 9
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 1
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 1

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 40
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 40

references

Steam Boiler processing

ID: MSc-1053
responsible/holder professor: Tucaković R. Dragan
teaching professor/s: Stupar M. Goran, Tucaković R. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal science engineering

goals
Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

learning outcomes
After successfully completing the course, the students will be able to:

• Perform the thermal boiler calculation.

• Calculate the heat balance of the mill drying process and chose the type and size of the mill.

• Perform the air and flue gases aerodynamic calculations of the steam boiler and choose an appropriate fan.

• Perform the strength calculation of basic elements of a steam boiler.

• Acquire the process of corrosion and wear of heating surfaces, as well as their protection.

theoretical teaching
Thermal calculation of the steam boiler heating surfaces - calculation of furnace, calculation of half-radiation and convection heating surfaces; Mill processes (coal dust characteristics, heat and material balance of mill drying process, mill control diagram);

Aerodynamic of the air and flue gas tract (balanced draft boiler, forced draft boiler and natural draft boiler); Hydrodynamics of steam boiler (hydrodynamics of water heater, evaporator and superheater); Steam boiler strength calculation; Corrosion, wear, defilement and cleaning of steam boiler elements.

practical teaching
Auditory exercises consist of demonstration exercises (Classification and construction of steam boilers with appropriate heating surfaces, auxiliary devices and equipment); Guidelines for preparation of the project - Based on information (obtained and calculated) in the project from subject Steam boiler elements and equipment, it is necessary to develop thermal calculations for given industrial steam boiler. In this project it is necessary to perform thermal calculation and dimensioning of the following heating surface - furnace (radiation evaporator), convective evaporator, steam superheaters, water and air heaters. After dimensioning the steam boiler heating surfaces, it's necessary to make the steam boiler drawing in three sections.

prerequisite
Necessary condition: Bachelor's degree;

Preferred passed exam: Steam boilers elements and equipments

learning resources
Books: Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of

Mechanical Engineering, Belgrade, 2010, (In Serbian); handouts which will be at student's disposal a week in advance

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 14
consultations: 0
discussion and workshop: 10
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 30

references

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

Steam Boilers elements and equipments

ID: MSc-1052
responsible/holder professor: Tucaković R. Dragan
teaching professor/s: Stupar M. Goran, Tucaković R. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal science engineering

goals
Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

learning outcomes
After successfully completing the course, the students will be able to:

• Calculate the material balance of the combustion process of solid fuels.

• Choose the excess air and calculate the enthalpies of combustion products.

• Choose the system of temperature control of a superheated vapor.

• Select the fuel bed combustion systems.

• Perform the preliminary thermal boiler calculation.

• Get to know more about the plant by visiting the thermal power plant.

theoretical teaching
Introduction; Solid fuels; Combustion material balance; Determination of excess air; Regulating the temperature of superheated steam - (Inherent regulation; Flue gas regulation; Steam regulation); Regulating the temperature of reheated steam; Apparatus for combustion of the opposite scheme - flat grate stoker; Apparatus for combustion of the cross scheme - chain and inclined grate stoker; Coal dust preparation systems; Devices for storage and transportation of coal; Mill constructions; Coal dust separators; Coal dust classifiers; Coal dust burners

practical teaching
Auditory exercises consist of demonstration exercises (Classification and construction of steam boilers with appropriate heating surfaces, auxiliary devices and equipment); Steam boiler heat balance; Working project - Worikng principle of industrial steam boilers; Determining the losses, efficiency and fuel consumption of the given steam boiler; Furnace dimensioning; Heat and material balance of steam boiler heating surfaces; Making of the boiler draft.

prerequisite
Necessary condition: Bachelor's degree ;

Preferred passed exam: steam boiler basics

learning resources
Books: Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); handouts which will be at student's disposal a week in advance

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 12
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 8
consultations: 0
discussion and workshop: 10
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 4
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 40
requirements to take the exam (number of points): 30

references

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

Thermal Power Plants and Heat Plants

ID: MSc-1054
responsible/holder professor: Tucaković R. Dragan
teaching professor/s: Tucaković R. Dragan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermal science engineering

goals
Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

learning outcomes
After successfully completing the course, the students will be able to:

• Acquire the essence of heat balance condensing thermal power plant.

• Be familiar with the regenerative heating feedwater schemes.

• Get to know about the water supply, transport fuels, slag and ash transport and flue gases depuration before its removal to the atmosphere.

• Get to know more about the principles of determining the location and general plan for thermal power plants and heating plants.

• Compare theoretical knowledge with plant derived from visiting a thermal power plant or heating plant.

theoretical teaching
Consumption of electrical and thermal energy; division of thermal power plants and technological scheme of thermal power plants; Efficiency and heat balance of condensation thermal power plant; Thermal efficiency and energy indicators of heating power stations; Steam parameters and reheating; Regenerative feed water heating; loss of steam, water and condensate and their fill; Power plant water supply; Transportation and storage of fuel in power plants; Transportation of slag and fly ash in thermal power plants; Filtration and drainage of flue gases into the atmosphere; Location and general plan for power plants;

practical teaching
Auditory exercises consist from demonstration exercises (Presentation and explanation of thermal power plant schemes; Representation and explanation of the power plant elements; Steam parameters of thermal power plants and reheating; Regenerative heating of condensate and feed water; The main operating facilities of domestic power plants; Displaying general plans for local power stations; Problems of exploitation of power plants); Instructions for making calculation task - Main features of the power plant block; Instructions for preparation of the paper - Elements of the power plant main facilities.

prerequisite
Necessary condition: Bachelor's degree;

Preferred passed exam: Steam boilers elements and equipments and Steam boiler processing

learning resources

Books: Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian); handouts which will be at student's disposal a week in advance

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 0
calculation tasks: 6
seminar works: 6
project design: 0
consultations: 2
discussion and workshop: 10
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 2
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 6
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 15
seminar works: 15
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Lj. Brkic, T. Zivanovic, D. Tucakovic: Thermal Power Plants, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, (In Serbian)

THERMOMECHANICS

Thermodynamics M

Thermodynamics M

ID: MSc-0202
responsible/holder professor: Komatina S. Mirko
teaching professor/s: Banjac J. Miloš, Gojak D. Milan, Komatina S. Mirko, Rudonja R. Nedžad, Todorović I. Ružica
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: thermomechanics

goals
Student should gain knowledge in thermodynamics and thermal devices and plants that are present in process engineering, thermal engineering and power engineering. Through practical and theoretical education should understand from thermodynamic aspect the transformation of thermal energy into mechanical work and gain physical fundamentals on phenomena that go on in steam turbine, gas turbine and refrigeration devices as well as in plants for drying various materials and air conditioning of corresponding spaces.

learning outcomes
Upon successful completion of this course, students should be able to:

•Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.

•Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.

•Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.

•Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.

•Recognize and describe the exergy of the open and closed thermodynamic system.

•Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.

•Recognize and determine the thermodynamic properties of wet gases and implement them in the analysis of thermomechanical processes in devices and facilities with moist air.

theoretical teaching
1.First law of thermodynamics for open thermomechanic system. Mass balance. Energy balance.

2.Second law of thermodynamics for open thermomechanic systems.

3.Exergy of closed and open thermomechanic systems.

4.Thermodynamic analysis of operation of basic thermomechanic devices and plants.

5.Thermodynamics of complex systems, outflow.

6.Humid air - devices and plants that operate with humid air.

practical teaching
1.Numerical exercises on First law of thermodynamics for open thermomechanic system.

2.Numerical exercises on Second law of thermodynamics for open thermomechanic systems.

3.Numerical exercises on exergy of closed and open thermomechanic systems.

4.Numerical exercises on thermodynamic analysis of operation of thermomechanic devices and plants.

5.Numerical exercises on thermodynamics of complex systems.

6.Numerical exercises on processes, devices and plants that operate with humid air.

prerequisite
Necessary: Physics, Thermodynamics B

learning resources
1. Milinčić, D., Voronjec, D.: Termodinamika, Mašinski fakultet, Beograd, 1990

2. Kozić, Đ.: Termodinamika, Inženjerski aspekti, Mašinski fakultet, Beograd, 2019

3.Vasiljević B,Banjac M.Mapa za termodinamiku,2020

4. Kozić, Đ., Vasiljević, B., Bekavac, V.:Priručnik za termodinamiku, Beograd, 2006

5. Hendauti za Termodinamiku M, sajt Mašinskog fakulteta, Beograd.

6.Voronjec, D., Kozić, Đ.: Vlažan vazduh, SMEITS, Beograd, 2005.

7. Vasiljević B,Banjac M.Priručnik za termodinamiku:tabele i dijagrami. 2020

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 25
laboratory exercises: 0
calculation tasks: 5
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 4
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 3
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 5
project design: 0
final exam: 35
requirements to take the exam (number of points): 20

references

Y.A.Cengel, M.A.Boles. Thermodynamics. An Engineering Approach. 5rd Edition, McGraw Hill, 2006.
A. Bejan: Advanced Engineering Thermodynamics, John Wiley & Sons, 1988
Moran M., Sharpio H., Fundamentals of Engineering Thermodynamics, John Wiley & Sons Ltd, 2006.

WEAPON SYSTEMS

Artillery Weapons Design

ID: MSc-1387
responsible/holder professor: Jevtić T. Dejan
teaching professor/s: Jevtić T. Dejan, Micković M. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: weapon systems

goals

Detailed analysis of design solutions for individual elements of artillery weapons. Detailed study of design methodologies for the main structural elements of weapons. Practical implementation of calculations for basic structural elements of artillery weapon through the realization of projects

learning outcomes

Mastering the calculation of basic parameters that characterize the function of individual pieces of artillery systems. Acquiring the ability of students to create their own software tool for the design of individual structural elements of artillery weapons. Qualifications for the design of the main structural elements of artillery systems.

theoretical teaching

Behaviour of the artillery weapon during firing. Design of muzzle brakes. Design of recoil mechanisms (recuperator, hydraulic recoil brake, hydraulic counterrecoil brake and fluid compensator). Design of devices and mechanisms of artillery mounts (cradle, top carriage, bottom carriage arms and equilibrators). Organization of surface and bore of gun barrel. Design of simple monoblock tube. Deformations and stresses in the walls of the doublelayer tube in rest state and when firing. Design of reinforced doublelayer tube. Basic concepts of autofrettage. Design of monoblock tube with autofrettage. The main types of breechblocks and their characteristics. Design of breechblock mechanism elements for: obturation, triggering and firing, opening, case ejection and closing. Characteristics and functions of breech rings. Design of breech rings.

practical teaching

Calculation of gun stability during firing. Design of muzzle brakes. Design of recoil mechanisms (recuperator, hydraulic recoil brake, hydraulic counterrecoil brake and fluid compensator). Design of devices and mechanisms of artillery mounts (cradle, top carriage, bottom carriage arms and equilibrators). Design of simple monoblock tube. Deformations and stresses in the walls of the doublelayer tube in rest state and when firing. Design of reinforced doublelayer tube. Basic concepts of autofrettage. Design of monoblock tube with autofrettage. Calculation of breechblock mechanism elements for: obturation, triggering and firing, opening, case ejection and closing. Design of breech rings.

prerequisite

Without specific conditions for attending the subject. Desirable - passed the exam in the subject Classical Armament Design.

learning resources

1. Micković D.: Design of Artillery Weapons - Handouts

2. Obrenović R.: Construction of Artillery Weapons, TŠC KoV JNA, Zagreb, 1975

number of hours: 45

> **active teaching (theoretical):** 18
> lectures: 12
> elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 6
laboratory exercises: 0
calculation tasks: 2
seminar works: 0
project design: 8
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)

feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references

Automatic Weapons

ID: MSc-1386
responsible/holder professor: Jevtić T. Dejan
teaching professor/s: Jevtić T. Dejan, Micković M. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: weapon systems

goals
Introducing of students to the basic elements of the automatic weapons. Formation of the system of differential equations that describe the movement of elements of the mechanisms of automatic weapons during the firing cycle. The study of methods for solving these differential equations. Preliminary design of various systems of automatic weapons.

learning outcomes
Mastering the calculation of basic parameters that characterize the function of various systems of automatic weapons. Acquiring the ability of students to create their own software tool for preliminary design of an automatic weapon. Qualifications for the design of individual elements of the automatic systems and optimisation of function of different types of automatic weapons.

theoretical teaching
Forces acting on the parts of an automatic weapon. Types of automatic weapons. Bolt locking systems and mechanical safety. Analysis of the cartridge case functions during firing. Analysis of differential equations of motion of elements in the mechanisms of automatic weapons with non-movable and movable receiver and methods for solving them. Characteristics of the movement of members of automatic weapon mechanisms. Determination of the transfer ratio and coefficient of efficiency of mechanisms that are used in the construction of an automatic weapon. Strikes in the mechanisms of automatic weapons. Movement of parts of automatics under the action of springs. Preliminary design of an automatic weapon: blow back operation systems (simple blow back, blow back with advanced primer ignition, delayed blow back, blow back with a locked breech), recoil operated systems (long recoil, short recoil), gas operation systems (long stroke pistons, short stroke pistons, direct gas action).

practical teaching
Calculation of forces acting on elements of an automatic weapon. Bolt locking systems and mechanical safety. Analysis of the cartridge case functions during firing. Methods of solving differential equations of motion of elements in the mechanisms of automatic weapons with non-movable and movable receiver.Characteristics of the movement of members of automatic weapon mechanisms. Determination of the transfer ratio and coefficient of efficiency of mechanisms that are used in the construction of an automatic weapon. Strikes in the mechanisms of automatic weapons. Movement of parts of automatics under the action of springs. Preliminary design of an automatic weapon: blow back operation systems (simple blow back, blow back with advanced primer ignition, delayed blow back, blow back with a locked breech), recoil operated systems (long recoil, short recoil), gas operation systems (long stroke pistons, short stroke pistons, direct gas action).

prerequisite
Desirable - passed exam in the subject Classical Armament Design.

learning resources
1. Micković D.:Handouts - Automatic Weapons

2. Vasiljević M.: Automatic Weapons, TŠC KoV JNA, Zagreb, 1970

number of hours: 30

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 7
laboratory exercises: 0
calculation tasks: 0
seminar works: 2
project design: 0
consultations: 3
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 0

references
Automatic Weapons - Engineering Design Handbook, US Army Materiel Command Pamphlet 706-260, 1970

Fire control systems

ID: MSc-1297
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written+oral
parent department: weapon systems

goals
Goal of subject is orientated to the student knowledge about basic technologies integrated in the battle that provides precise engagement and reliable shooting of target by direct, indirect or other type of weapon fire. Modern systems employed and design by the basic knowledge about LOS, NLOS, and other shooting elements and principles understand sensor principles, automatic devices and software proceedings, based on ballistic shooting elements. Modern navigation and position principles of weapon fire represented by fundamental vectoral battle mechanics, of platforms motion, targets and projectiles flight in FCS composition models. Processes are represented by artillery, AD, BMD, and armored vehicles battle mechanics and platforms and units integrated systems.

learning outcomes
Student is trained and educated to solve individual employment of weapon and their integrations of performances with other non weapon helping defense equipment and battle functions. Those understand shooting functions precision positioning and errors estimation, preparing weapon for selected target mission, and ballistics and flight mechanics estimation for optimal target shooting. Also student achieve basic knowledge for Command information battle technology and weapon fire precision strike technology. Software, autoimmunization and mechatronics sensor integration, in the battlefield mechanics of unsteady state vectoral proposals provides FCS software and hardware knowledge, for weapon designers.

theoretical teaching
1. Ballistic trajectories in shooting principles for LOS and NLOS projectiles and types of weapon fire.

2. Conventional indirect fire artillery shooting and FCS.

3. Shooting artillery of armored vehicles in motion and direct fire autoimmunization stabilization and errors estimations. Devices and equipment of weapon stabilization and equipment for FCS

4. Air defense gun systems and AD combat platforms and AD responsibilities areas

5 Sensors, tracking targets equipment, sighting, automatic optoelectronics, and IR technology laser range finders and navigation GIS and GPS systems and errors performances and analyzes.

practical teaching
1. Examples of trajectories and corresponding tactical weapon type.

2. Armored vehicles and tank weapons stabilization and shooting FCS integration

3. Automatic control principles for tracking and shooting for air defense platforms and systems /gun and missiles

1.4. UAV and navigating principles of GIS and GPS precision strike on the target., and new concepts of C2I, C3I, C4I, C4ISTAR, in command and control FCS navigation.

prerequisite
No requirements.

learning resources
1. Milinovic M.: Layhandout - Fire control systems.

number of hours: 30

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 6
laboratory exercises: 3
calculation tasks: 0
seminar works: 0
project design: 3
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 30

references
MIL-HDBK-799(AR): FIRE CONTROL SYSTEMS - GENERAL, April 1996.

Flight Dynamics and Aerodynamic of Projectiles

ID: MSc-1084
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: weapon systems

goals

Introduce students to the basics of calculations and modeling the dynamics of flight of the projectile. Introduce students to the basics of the structure and implementation of the program for the modeling of the dynamics of flight. The introduction of the experimental methods and analyses of flight tests. Introduce students to the basics of aerodynamic calculations. Introduce students to the basics of the structure and implementation of the program for calculations of aerodynamic of the projectile. Introduction to experimental methods in aerodynamics.

learning outcomes

Student is qualified for independent work on the calculations and flight dynamics modeling of guided and unguided projectiles. Student is qualified for experimental work in the field of flight testing. Student is qualified for independent work on the calculations of aerodynamic characteristics of guided and unguided projectiles. Student is qualified for experimental work in the field of aerodynamic tests.

theoretical teaching

Stability of aerodynamically stabilized projectiles (static stability, dynamic stability; transverse resonance oscillations and rolling). Stability of gyro-stabilized projectiles (static stability dynamic stability). Maneuverability of guided missile (control methods; rolling stabilization, control by the normal force). Projectile flight dynamics modeling (Introduction to modeling, modeling with 3 and 6 degrees of freedom). Quaternions and transformation using quaternions. Modeling unguided missiles (introduction to modeling unguided missiles; elaboration of case modeling). Modeling guided missile (introduction to the modeling of guided missiles; elaboration of case modeling). The basic method of aerodynamic calculations (division method of aerodynamic calculations; introduction to the method of breaking up into components; aerodynamic tests). The aerodynamic characteristics of the body (body geometry, calculation methods aerodynamics of the body). The aerodynamic characteristics of the wings and fins (geometry; calculation methods). Aerodynamic interference (interference wing-body, wing-wing interference). Software packages for aerodynamic calculations (base structure; standard software packages). Aerodynamic design (methods of aerodynamic design, selection of parameters, case study).

practical teaching

Stability aerodynamically stabilized projectiles (assignments) Stability gyro-stabilized projectiles (examples) Maneuverability of guided missile (assignments) Fundamentals of projectile flight dynamics modeling (modeling packages 6DOF, MATLAB, Simulink). Modeling unguided missiles (case modeling). Modeling guided missile (case modeling). The basic method of aerodynamic calculation (Introduction to the method of breaking up the components). The aerodynamic characteristics of the body (Examples). The aerodynamic characteristics of the fins (Examples). Aerodynamic Interference (Examples). Software packages for aerodynamic calculations (case study). Aerodynamic design (examples).

prerequisite

none

learning resources

1. Blagojević Đ .: The dynamics of flight of the projectile, Belgrade, 2004;

2. Zipfel, P.H .: Modeling and Simulation of Aerospace Vehicle Dynamics, New York, 2007.

3. Djordje Blagojevic, Aerodynamics of the projectile - handouts, Belgrade, 2010.

4. Slobodan Janković, aerodynamics of of the projectile, Faculty of Mechanical Engineering, Belgrade, in 1979.

number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 35
auditory exercises: 5
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 45
requirements to take the exam (number of points): 35

references

McCoy, R.L.: Modern Exterior Ballistics, Shiffer Publishing, 2012.
R. Nielsen, Missile Aerodynamics, New York, 2001.

Interior Ballistics

ID: MSc-1385
responsible/holder professor: Jevtić T. Dejan
teaching professor/s: Jevtić T. Dejan, Micković M. Dejan
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: weapon systems

goals
Study of methods of solving the basic task of interior ballistics and ballistic design. The study of the basic characteristics of special types of weapons. Consideration of methodology of interior ballistic tests.

learning outcomes
Mastering the calculation of direct and indirect task of interior ballistics of various types of weapons, and the methodology of interior ballistic tests.

theoretical teaching
Introduction to interior ballistics.

Gun propellants and their characteristics.

Basic processes and laws during firing.

Solution of the basic task of interior ballistics (Task statement. The analytical method of solving. Propellant gas temperature calculation. Tabular method of solving the basic task of interior ballistics).

Ballistic design.

The solution of the task of internal ballistics for the combined (howitzer) charge.

Interior ballistics of recoilless weapons.

Interior ballistics of mortars.

The introduction of interior ballistic corrections (Ermolaev method).

Interior ballistic tests (objective, classification and measuring parameters). Interior ballistic test preparation. Pressure measurement. Measurement of gun muzzle velocity. Measuring of recoil system impulse.

practical teaching
Production of gunpowder.

Basic processes and laws during firing.

Solution of the basic task of interior ballistics (Task statement. The analytical method of solving. Propellant gas temperature calculation. Tabular method of solving the basic task of interior ballistics).

Interior ballistic design (Task of gun tube design. Interior ballistic characteristic of weapons. General dependence of structural tube characteristics on charge conditions. Directive diagram and its analysis).

The solution of the task of interior ballistics for the combined (howitzer) charge.

Introduction of interior ballistic corrections (Ermolaev method).

prerequisite
Passed exams (preferred): Thermodynamics B, Fundamentals of Projectiles Propulsion, Physics of Explosive Processes

learning resources

1. Jaramaz, S, Mickovic, D.: Interior ballistics, Faculty of Mechanical Engineering, Belgrade, 2011.

2. Interior ballistic design tables

3. Correctional coefficients tables

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 4
laboratory exercises: 0
calculation tasks: 4
seminar works: 0
project design: 8
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 0

references

Launching Theory

ID: MSc-1298
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: project design
parent department: weapon systems

goals
The basic purpose of the subject is aimed to the student knowledge and skills of applied launching ballistic mechanics, gas dynamics of missiles starting motion, on-in, the launcher, and relative interactive motions of combat platforms and launcher .The basic theoretical goal is to introduce students with simplified models of disturbances mechanics and to calculate critical disturbance cases and their influences on the launching and final missile shooting errors. Also, goals are to evaluate global design performances of launcher by functional and exploitation combat loads, as the input for strain and stress integration analyses.

learning outcomes
Student achieve capabilities for individual analyzes, preliminary integration and syntheses of launching mechanics applied on the launcher mounted on the combat platform of any type or design. Accepted methodology provides student ability to calculate and verify missile weapon efficiency, by recognizing loads and disturbances composed in the missile weapon errors, caused by tube, rail or container launcher type and their processes, integrated and jointed with the combat platforms, of any vehicle or vessel.

theoretical teaching
1. Launching mechanics and disturbances of the missiles and rockets from the rail type of launcher

2. launching mechanics of the tube launcher and forced gas generating motion and disturbances

3. Vertical platforms launching, open and tubes closed and their critical disturbances

4. Ripple rocket launching and combat and launching recoil and attack forces, and launcher and vehicle stability and disturbances.

practical teaching
1. Solution examples for low spin fin stabilized and high spin gyro stabilized unguided

Rockets from the tube initial spin, and from the smooth barrel launchers.

2. Solutions of initial rocket flight and mathematical calculations of barrel length.

Active flight calculations for unguided rockets.

3. Vertical launching errors and stability calculations .Zero initial velocity launchers

4. Loads and disturbances calculation on the missiles launching of guided flight

prerequisite
-

learning resources
1. M. Milinovic: Basics of missiles and launchers design chapters from launcher design, University of Belgrade Faculty of ME 2002.

2. O. Vucurovic: Launchers design (serb), University of Belgrade Faculty of ME 2002.

number of hours: 30

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 6
laboratory exercises: 3
calculation tasks: 0
seminar works: 0
project design: 3
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 2
colloquium, with assessment: 0
test, with assessment: 0
final exam: 2

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 30
calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 30

references

MILITARY HANDBOOK: DESIGN OF AERODYNAMICALLY STABILIZED FREE ROCKETS, MIL-HNDBK-762(MI), 1990.
Rosser J.B. and others: Mathematical theory of rocket flight, McGRAW-HILL BOOK COMPANY, 1947.

Missile design and launchers

ID: MSc-1299
responsible/holder professor: Marković D. Miloš
teaching professor/s: Marković D. Miloš
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written+oral
parent department: weapon systems

goals
Goal of subject is to achieve student in detail contents of missiles subsystems its integration and key performances of flight and terminal phase, functions. Goal of knowledge's are directed on the technology roll and influences on the particular quality and quantity of missiles performances. Missile is considered as the flight vehicle and ammunition for the different payload purposes and defense missions . Student developing detailed skills and knowledge for design, analyzes, syntheses of missiles and rockets and about its advanced technology applications on the component design its research and methodology of calculations and development.

Goal of subject is to achieve student knowledge in two basic launcher equipment

Sub systems. Sub systems of equipment and devices for shooting and missiles positioning and launching, and subsystems of equipment and devices for other defense and military integrated functions available on the self-propelled weapon launcher.

Student through practical project research of concept and component integration realize knowledge of software and hardware integration on the launcher and new technologies implementation on the self propelled or portable weapon missile launching Systems.

learning outcomes
Student achieve level of individual designer of tactical missiles and other jobs and purposes of missile syntheses .Also, student is accomplished for the analyzes and syntheses of all levels and types in the missile and ammunition rocket technologies by tools of applied mechanics and software analyzes of integrative rocket and missile technologies and performances .Parametric composition of missile flight mechanics, special ballistics and rocket propulsion propellants performances and other interdisciplinary integration selection and estimations, is comprehension output of subject.

Student realizes skills and knowledge for individual integrating of launcher weapon,

their conceptual solutions and critical thinking and opinion about advantages for applied Systems and sub systems. Also launcher and its equipment is integrative design system test for knowledge of missile system design and defense functions. Student through practical selections of functions and its solutions gets knowledge of compromises in technology possibilities and threshold performances of practical use and its requirements.

theoretical teaching
Role of missiles in military use. Missiles configuration. The concept of missile components dispositions. Components and subassemblies, their structural and functional connection, especially in guided, especially in unguided missiles. Determination of missile initial mass and solid rocket motor performances. Missile propulsion integration. Aerodynamic configurations of guided and unguided missiles. Aerodynamic design. Analyzes of guidance laws and their influence on guided missile design. Dynamic performances of the missile. Fundamentals of autopilot and role in guided missile design. Missile control systems. Missile loads during flight. Structure and structure materials of unguided and guided missiles. Missile component stress analyses. Content of subsystems for MLRS, AT, AD, BM, launchers mechanisms integrated for missiles launching, and shooting, devices functional and

equipment design. Equipment for launching stability, energy supply and other conditions for functional and environmental uses of defense and functional missiles weapon technology. Launchers stability analysis and interactions with missiles.

practical teaching
1. Missiles projectiles preliminary design guided and unguided 2. Concept of missile tactical mission, preliminary design of requirements and performances 3. Seminar case study of missile or rocket preliminary design for new missile of chosen mission, presentation of solution. 4. Critical technology in project designs a consulting for solutions optimization. 5. Project solution idea. 6. Kinematics and dynamics of launching mechanisms in joint work with system integration concept, elevation mechanism, stabilization mech. direction mechan., fire mech. and launching forces estimation. 7. Presentation of joint launcher project and its substitution with critical estimations of components, and technology.

prerequisite
No requirements.

learning resources
1. Milos Markovic: Handout - Missile design and launchers, Belgrade 2020.

2. Vucurovic O.: Basis of missile design, University of Belgrade, Mechanical engineering, 2003.

3. Vucurovic O.: Design issues of launching devices, University of Belgrade, Mechanical engineering, 2006.

4. Milinovic M.: Fundamentals of Rocket and Launcher Design - Chapter in Launcher Design, University of Belgrade, Mechanical engineering, 2002.

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 10
laboratory exercises: 10
calculation tasks: 0
seminar works: 0
project design: 10
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 2
check and assessment of seminar works: 0
check and assessment of projects: 10
colloquium, with assessment: 0
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 30

calculation tasks: 0
seminar works: 0
project design: 30
final exam: 30
requirements to take the exam (number of points): 35

references

E. Fleeman, Missile design and system engineering. American Institute of Aeronautics and Astronautics, 2012.
Zarchan P.: Tactical and Strategic Missile Guidance, Volume 239, Progress in Astronautics and Aeronautics, 2012.
Krasnov N.F. et al.: Rocket aerodynamics, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, June 1971
Siouris G. M.: Missile Guidance and Control Systems, Springer, 2004.
Архангельский И. И.: ПРОЕКТИРОВАНИЕ ЗЕНИТНЫХ УПРАВЛЯЕМЫХ РАКЕТ, МОСКВА, Издательство МАИ 2001.

Missile guidance and control

ID: MSc-1085
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: weapon systems

goals
Acquiring basic knowledge in the field of missile guidance and control with the possibility of applications in the fields of research and development, designing, manufacturing, marketing, operational use and analysis of modern guided missiles. Mastering the methodology of the calculations of dynamic characteristics of guided missiles (maneuverability, stability, etc. The eigen frequencies.) and autopilot synthesis and guidance law for the method of proportional navigation.

learning outcomes
The student acquires general knowledge in the areas of analysis and synthesis system of guided missiles that enables participation and communication in work teams involved in the development of guided missiles. With the use of modern software tools developed in MATLAB and Simulink, are qualified for the trajectory calculation of guided missiles, aerodynamic transfer function calculation and the synthesis of the autopilot and the missile guidance system. It has a basic knowledge of verification and assessment of the quality of guidance system.

theoretical teaching
Introduction to the theory of guidance and control of the missiles (discusses the basic principles of guidance and control). Analysis of dynamic characteristics of missiles and calculation of aerodynamic transfer functions. Basic requirements and methods of designing autopilots (Block is dedicated to improving the dynamic properties of rockets by autopilot use). Theoretical basis of proportional navigation (We examine the proportional navigation as one of the fundamental laws of guidance)

practical teaching
The practical realization of guided missiles (analyzed various construction solutions of guided missiles to review the role of guidance and control subsystem. The application of MATLAB and Simulink in design). Designing pitch and roll autopilots. Simulation homing systems (applying SIMULINK program, students are trained in the selection parameters PN). The project of the system of homing missile (Project includes aerodynamic function transfer calculations and synthesis of the autopilot and homing system)

prerequisite
None.

Passed exams (preferably): flight dynamics and aerodynamics of projectiles, Fundamentals of automatic control

learning resources
Cuk, D .: Lectures in course Missile guidance and control, Faculty of Mechanical Engineering, Belgrade, 2002 (handouts)

number of hours: 30

active teaching (theoretical): 8
lectures: 6
elaboration and examples (revision): 2

active teaching (practical): 16
auditory exercises: 7
laboratory exercises: 3
calculation tasks: 3
seminar works: 0
project design: 3
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 3
colloquium, with assessment: 0
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 40
final exam: 50
requirements to take the exam (number of points): 25

references
P. Garnel: Guided Weapon Control System, Pergamon Press, New York, 1980.;
Danilo Ćuk: Design of Beam-Riding Laser Guidance System,MTI, 1998.
Danilo Ćuk: Theory of Homing Systems, Proportional Navigation,MTI, 1998.

Missile navigation, guidance and control algorithms

ID: MSc-1388
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: weapon systems

goals

Acquiring knowledge in the field of navigation guidance and control of missiles with the possibility of application in the fields of research and development, design, production, marketing, operational use and analysis of modern guided missiles. Mastering the methodology of calculating the dynamic characteristics of guided missiles. Acquisition of knowledge in the field of autopilots, different autopilot algorithms, as well as their synthesis. Introduction to different types and algorithms of control laws and their synthesis. Mastering inertial navigation as well as getting acquainted with algorithms for coupling inertial navigation with other types of navigation.

learning outcomes

The student acquires general knowledge in the field of analyzing and synthesizing a GNC system of guided missiles that enable participation and communication in work teams involved in the development of guided missiles. The student is trained for independent work in the fields of navigation algorithms as well as the selection of the necessary inertial seasons either for the navigation systems or for the needs of the missile guidance and control system. The student masters various algorithms and techniques from the calibration of inertial sensors and elements of the guidance and control system to synthesis of guidance algorithms and autopilots, algorithms for missiles stabilization. With the use of modern software environments MATLAB and SIMULINK, the student is trained to apply and analyse algorithms in this field.

theoretical teaching

Basics of inertial navigation. Historical development of inertial navigation and strap-down INS. Coordinate frames. Kinematic Euler equation and algorithms of solving (Euler's angles, quaternions, Hamilton's parameters, Rodriges's theorem). Gyroscopes and accelerometers. Calibration of inertial units, testing and error correction. The basics of the global positioning system. Aided navigation systems.

Introduction to the theory of guidance and control of the missiles (the basic principles of guidance and control). Analysis of dynamic characteristics of missiles and calculation of aerodynamic transfer functions. Requirements and methods of designing autopilots. Analyses and syntheses of proportional navigation, the command to LOS guidance and different approaches for trajectory correction and trajectory guidance.

practical teaching

INS algorithms. Influence of sensor errors on inertial navigation. Calibration algorithms. Algorithms of integrated navigation systems.

The practical realization of guided missiles (analyzed various construction solutions of guided missiles to review the role of guidance and control subsystem. The application of MATLAB and Simulink in design). Designing pitch, yaw and roll autopilots. Each student should solve a project of guidance system for the given missile data.

prerequisite

none

learning resources

Titterton, D.H. and Weston, J.L., ”Strapdown Inertial Navigation Technology – 2nd edition”, IEE Radar, Sonar, Navigation and Avionic Series 17, ISPB 0-86341-358-7, 2004

Savage, P.G., ”Strapdown Inertial Navigation Integration Algorithm Design Part 1: Attitude Algorithms”, Journal of Guidance, Control, and Dynamics, Vol. 21, No. 1, pp. 19-28, Jan.-Feb. 1998

Savage, P.G., ”Strapdown Inertial Navigation Integration Algorithm Design Part 2: Velocity and Position Algorithms”, Journal of Guidance, Control, and Dynamics, Vol. 21, No. 2, pp. 208-221, Mar.-Apr. 1998

Salychev, O., “Inertial Systems in Navigation and Geophysics”, Bauman MSTU Press, ISBN 5-7038-1346-8, MOSCOW 1998

Salychev, O., “Applied Inertial Navigation: Problems and Solutions”, Bauman MSTU Press, ISBN 5-7038-2395-1, MOSCOW 2004

Cuk, D .: Lectures in course Missile guidance and control, Faculty of Mechanical Engineering, Belgrade, 2002 (handouts)

number of hours: 75

active teaching (theoretical): 25
lectures: 20
elaboration and examples (revision): 5

active teaching (practical): 35
auditory exercises: 5
laboratory exercises: 5
calculation tasks: 10
seminar works: 0
project design: 15
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 5
colloquium, with assessment: 5
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 25
final exam: 45
requirements to take the exam (number of points): 0

references

P. Garnel: Guided Weapon Control System, Pergamon Press, New York, 1980.;
Danilo Ćuk: Design of Beam-Riding Laser Guidance System,MTI, 1998.

Danilo Ćuk: Theory of Homing Systems, Proportional Navigation,MTI, 1998.
Titterton, D.H. and Weston, J.L., "Strapdown Inertial Navigation Technology – 2nd edition", IEE Radar, Sonar, Navigation and Avionic Series 17, ISPB 0-86341-358-7, 2004
Salychev, O., "Applied Inertial Navigation: Problems and Solutions", Bauman MSTU Press, ISBN 5-7038-2395-1, MOSCOW 2004

Missile Propulsion

ID: MSc-0
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: weapon systems

goals
Introducing students to the fundamentals of determination of rocket engines performance parameters. Introducing students to the design of rocket engines with liquid and solid propellants, as well as special units of liquid rocket engines. Fundamentals of thrust vector control of rocket motors. Introduction to methods of rocket engines testing.

learning outcomes
After successful completion of the course, students should be able to:

- define the performance parameters of rocket engines,

- independently calculate the main structural parts of solid propellants rocket engines,

- analyze all subsystems of liquid propellants rocket engines,

- understand different concepts of the thrust vector control systems of a rocket,

- apply the acquired knowledge in the field of experimental work on the tests of rocket engines.

theoretical teaching
1. Performance parameters of solid propellants rocket motors (Fundamentals of combustion of solid rocket propellants; pressure equation in the solid rocket motor, pressure stability, thrust of rocket engine)
2. Performance parameters of liquid propellants rocket engines (Fundamentals of combustion of liquid propellants; characteristic length and time of residence; ignition, injectors)
3. Heat transfer in rocket engines (Fundamentals of heat transfer in rocket engines, thermal protection, cooling of liquid propellants rocket engines)
4. Design of rocket engine with solid propellants (Fundamentals of design of solid propellants rocket motors, thrust vector control, nozzle design, chamber design; design of propellant charge)
5. Design of rocket engines with liquid propellants (Fundamentals of design of liquid propellants rocket engines; chamber design; turbo-pump power systems; tank pressurization systems; thrust vector control systems)
6. Testing of rocket engines (Research, development and verification tests)

practical teaching
1. Performance parameters of solid propellants rocket motors (Examples of calculations; introduction to the software package BALIST)

2. Performance parameters of liquid propellants rocket engines (Examples of calculations; introduction to the software package COMBUS)

3. Heat transfer in rocket motors (Calculation of thermal protection of rocket motor with solid propellants; Calculation of chamber cooling in the case of liquid propellants rocket engine)

4. Design of rocket engines with solid propellants (Examples of design calculations)

5. Design of rocket engines with liquid propellants (Examples of the calculation of subsystems)

prerequisite
Passed exams (preferred): Fundamentals of projectile propulsion, Thermodynamics B

learning resources
1. Elek, P.: Missile propulsion - lectures, Faculty of Mechanical Engineering, Belgrade, 2012. (in Serbian)

2. Blagojevic, Dj.: BALIST - Program for calculation of performance parameters of solid propellant rocket motors, Belgrade, 1998.

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 9
laboratory exercises: 3
calculation tasks: 3
seminar works: 3
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references
Jaukovic, Dj.: Fundamentals of rocket engineering; Part I: Rocket propulsion, Military Academy, 1972. (in Serbian)
Jojic, B., Blagojevic, Dj., Pantovic, A., Milosavljevic, V.: Hanbook for sounding rockets design, Part II: Propulsion group, SAROJ, Belgrade, 1978. (in Serbian)
Sutton, G.P., Biblarz, O.: Rocket propulsion elements, 7 ed, John Wiley and Sons, 2001.
Hill, P., Peterson, C.: Mechanics and Thermodunamics of Propulsion, Pearson, 2010.

Optical devices and optoelectronics

ID: MSc-1332
responsible/holder professor: Todić N. Ivana
teaching professor/s: Todić N. Ivana
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 2
final exam: written
parent department: weapon systems

goals
The aim of this course is to enable students, future mechanical engineers - designers of military systems, the acquisition of knowledge necessary to the cooperation with the designers of complex optical and optoelectronic systems. After completion of lectures and exercises, students should be able to set and calculate basic optical systems.

learning outcomes
The subject allows students, future mechanical engineers - designers of military systems to:

- Set up basic optical systems (lenses, working systems, oculars, Kepler and Galileo's scheme of telescope system);

- Calculate an optical system using sophisticated codes for optical system design.

theoretical teaching
Basic assumptions and definitions used in optics.

Ideal and paraxyal optics as the basic approximations used in the design of optical systems.

1. Theory of aberrations and the theory that defines the deviation of real established character from an ideal character.

2. Rating the quality of image formed by optical systems.

3. Losses of light energy during propagation through the optical system.

4. Basic parameters and laws in optoelectronics. Principles of the laser. Main components that make up the laser system. Laser rangefinder.

practical teaching
1. Description of the major optical components that make up the conventional optical systems.

2. Calculation of ideal and paraxyal rays propagation through the optical system.

3. Calculation of real rays propagation through the optical system.

4. Design of a telescopic system (Kepler and Galileo's telescope system scheme).

5. Working principle of the picture amplifier.

6. Working principle of optical radiation detectors. Explained in detail the working principle of CCD detectors.

7. Working principle of the laser and review of basic components that make up the laser system. Explained in detail the laser rangefinder.

8. Working principle of thermal imaging and review of the basic components of different types of thermal imaging units

prerequisite
There are no special conditions for attending the subject.

learning resources

1. Vasiljević D.: Optical Devices and Optoelectronics, Facultz of Mechanical Engineering, Belgrade, 2005

2. Software package OSLO – Optical Surface Layout and Optimization LT ver. 5.4

OSLO Optics Reference Manual, CCO

number of hours: 30

active teaching (theoretical): 12
lectures: 8
elaboration and examples (revision): 4

active teaching (practical): 12
auditory exercises: 6
laboratory exercises: 0
calculation tasks: 0
seminar works: 6
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 6
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 1
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 20
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Physics of explosive processes

ID: MSc-1136
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 6
final exam: written
parent department: weapon systems

goals
The goal of course is that students learn the basic principles of combustion of materials and physics of explosion which are of importance for the realization of a function of weapon systems. Students should learn the contents of the process of explosion and burning of gunpowder and rocket propulsion materials as integrated chemical-technological systems.

learning outcomes
Student gets knowledge for calculations of physics of explosion processes that influence warhead mechanisms and target efficiency. Student understand influencing parameters on the energy release by combustion processes. Student forms the scientific and experimental base for the development and creation of new knowledge in the field of energetic materials and energy release processes in defense technologies.

theoretical teaching
1. Fundamentals of thermochemistry and thermodynamics of the explosive processes
2. Explosives sensitivity to external influences
3. Fundamentals of the hydrodynamic theory of detonation
4. The effect of explosions on the surrounding environment
5. Contact detonations. Active part of the explosive charge
6. Explosive propulsion. The formation of plane detonation wave
7. General assumptions and laws of ignition of fuel-oxidizer systems and exothermic reaction
8. Combustion of solid rocket propellants, powders and pyrotechnic mixtures (kinetics and thermochemistry)
9. Combustion products and energy characteristics of the various types of fuel mixtures and methods of measuring the burning rate

practical teaching
1. Calculation of thermochemistry and thermodynamics of the explosive processes
2. Explosives sensitivity to external influences. Applications
3. Fundamentals of the hydrodynamic theory of detonation. Selected examples
4. The effect of explosions on the surrounding environment. Selected examples
5. Contact detonations. Active part of the explosive charge
6. Explosive propulsion. The formation of plane detonation wave. Examples
7. Ignition and combustion of gas and liquid reactants and boundary conditions
8. Kinetic properties of powder and rocket propellants and models of decomposition of solid fuels
9. External influences and methods of measuring kinetic and energy parameters in different environmental conditions

prerequisite
There are no obligatory prerequisites. Passed exam preferred: Fundamentals of projectile propulsion

learning resources

1. Jaramaz, S.: Physics of Explosion, Faculty of mechanical Engineering, Belgrade, 1997.

2. Maksimovic, P.V.: Technology of explosive materials, Military Publishig Company,

Belgrade, 1972 (in Serbian)

3. Adzic, M.: Fundamentals of combustion, Faculty of Mechanical Engineering, Belgrade, 2007 (in Serbian)

4. Milinovic, M.: Principles of combustion of solid propellants, Принципи сагоревања

чврстих погонских материја, Faculty of Mechanical Engineering, Belgrade, 2007 (in

Serbian)

number of hours: 75

active teaching (theoretical): 30
lectures: 20
elaboration and examples (revision): 10

active teaching (practical): 30
auditory exercises: 6
laboratory exercises: 8
calculation tasks: 16
seminar works: 0
project design: 0
consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 15
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 0
check and assessment of projects: 0
colloquium, with assessment: 10
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 60
laboratory exercises: 0
calculation tasks: 0
seminar works: 0
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Projectile design

ID: MSc-1138
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: weapon systems

goals
The main objective of the course is that students understand the importance, the basic concepts and methods of projectile design as an integral part of the science of weapons systems. Students should understand the key ideas about the types and purpose of projectiles, safety in the use and mechanisms of action.

learning outcomes
Student gets contemporary knowledge about the main types of projectiles (high-explosive, armor-piercing, special) and the basics of their design. Student could use methods of calculation of different types of projectiles and their components.

theoretical teaching
1. Introduction to the projectile design. Basics of projectile safety during the movement in the gun barrel. Stress of projectile elements in the gun barrel.

2. High-explosive projectiles. Fragmentation warhead. Number, individual mass and shape of fragments. Configuration and direction of the fragments beam. Fragments' ballistics. Efficiency and specific efficiency of fragmentation warhead. Blast effect.

3. Shaped charge projectiles. Theoretical basis for a shaped charge effect. Hydrodynamic theory. Misznay-Shardin's effect.

4. Armor-piercing projectiles. The influence of the mechanical characteristics of the projectile and armor on the penetration process.

5. Special purpose projectiles. Design characteristics of special-purpose projectiles. Smoke projectiles. Illuminating projectiles. Incendiary projectiles. Aerosol projectiles.

practical teaching
1. Introduction to projectile design. Projectile safety during movement in the gun barrel. Stress of projectile elements in the gun barrel. Selected problems.

2. High-explosive projectiles. Fragmentation warhead. Number, individual mass and shape of fragments. Configuration and direction of the fragments beam. Fragments' ballistics. Efficiency and specific efficiency of fragmentation warhead. Examples

3.High-explosive projectiles. Measures to increase the fragmentation effect of the projectile. Blast effect. Examples.

4. Shaped charge projectiles. Examples.

5. Term paper - Preparation of seminar work with the subject determined by arrangement with the student.

6. Armor-piercing projectiles The influence of the mechanical characteristics of the projectile and armor on penetration process. Examples.

7. Armor-piercing projectiles. Depth of penetration. Analysis of selected examples.

prerequisite
Passed exam (preferred): Physics of explosive processes.

learning resources
1. Jaramaz, S.: Warheads Design and Terminal Ballistics, Faculty of Mechanical Engineering, Belgrade, 2000.

2. Stamatovic, A.: Projectile design, Ivexy, Belgrade, 1995.

3. Jaramaz, S.: Manuscript for lessons, 2016.

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 4
laboratory exercises: 0
calculation tasks: 10
seminar works: 2
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 2
check and assessment of projects: 0
colloquium, with assessment: 2
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Skill Praxis M - SIN

ID: MSc-1218
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: seminar works
parent department: weapon systems

goals
Practical experience and student's stay in the environment in which he will realize his professional career. Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineer in such a business system.

learning outcomes
Students get practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career.

Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, in the context of his future professional competence. Personal contacts and acquaintances are established that student will be able to use during study or entering into future employment.

theoretical teaching
Teaching is practical.

practical teaching
Practical work involves working in organizations that perform various activities in connection with mechanical engineering. Selection of thematic areas and commercial or research organizations is carried out in consultation with the concerned professor.

Generally a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations engaged in mechanical equipment maintenance, public utility companies and some of the laboratories at Faculty of Mechanical Engineering.

The practice may also be made abroad. During practice, students must keep a diary in which he will enter a description of the tasks performed, the conclusions and observations. Following the practice they must make a report to defend of the subject professor. The report is submitted in the form of the paper.

prerequisite
No.

learning resources
number of hours: 90

> **active teaching (theoretical):** 0
> lectures: 0
> elaboration and examples (revision): 0
>
> **active teaching (practical):** 80
> auditory exercises: 0
> laboratory exercises: 0
> calculation tasks: 0
> seminar works: 80
> project design: 0

consultations: 0
discussion and workshop: 0
research: 0

knowledge checks: 10
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 5
check and assessment of projects: 0
colloquium, with assessment: 0
test, with assessment: 0
final exam: 5

assessment of knowledge (maximum number of points - 100)
feedback during course study: 0
test/colloquium: 0
laboratory exercises: 0
calculation tasks: 0
seminar works: 60
project design: 0
final exam: 40
requirements to take the exam (number of points): 30

references

Terminal Ballistics

ID: MSc-0
responsible/holder professor: Elek M. Predrag
teaching professor/s: Elek M. Predrag
level of studies: M.Sc. (graduate) academic studies – Mechanical Engineering
ECTS credits: 4
final exam: written
parent department: weapon systems

goals
The main goal of the subject is that students understand the importance, the basic concepts and methods of terminal ballistics, as an integral part of the science of weapons systems. Students should understand the key ideas about the projectile/target interaction and their use in projectile design as well as ballistic protection.

learning outcomes
After successful completion of the course, students should be able to:

- define all types of projectiles/warheads action on targets,
- calculate the main parameters of all types of penetration processes,
- analyze the characteristics of blast effect,
- model the mechanisms of high-explosive projectiles fragmentation effect,
- apply the experimental methods for determination of projectile efficiency parameters,
- understand the functional composition and the fundamentals of fuze design.

theoretical teaching
1. Scope of terminal ballistics
The effect of projectile on target. Types of projectiles. Types of targets. Tasks of terminal ballistics. Behavior of materials under dynamic conditions.
2. Penetration mechanics
Fundamentals of penetration mechanics. Armor piercing projectiles. Experimental determination of penetration. Long rod penetration. Shaped charge jet penetration.
3. Fragmentation
Mechanism of projectile fragmentation. Fragment velocity. Mass distribution of fragments. Experimental determination of the efficiency of fragmentation projectile.
4. Blast effect
Shock wave, pressure and impulse. Blast effect of projectiles. Underground explosion. Underwater explosion
5. Fuzes
Classification of fuzes. Functional composition of fuzes. Calculation of reliability and safety of fuzes. Testing of fuzes.

practical teaching
1. Approaches to solving problems in terminal ballistics
Examples of target kill probability. Models of material behavior under dynamic loads.
2. Penetration/Perforation
Simple penetration models penetration for thin targets. Penetration at high velocities.
3. Penetration/Perforation
Models of shape charge jet and long rod penetration.
4. Workshop - Preparation of the paper with a topic that is determined by arrangement with the student.

5. Fragmentation
Experimental evaluation of the efficiency of projectile fragmentation.
6. Blast effect
Determination of blast effect parameters.
7. Fuzes
Models of the effect of certain types of fuzes. Calculation of reliability and safety of fuzes.

prerequisite
Exams passed (preferred): Projectile design, Physics of explosive processes

learning resources
1. Jaramaz, S.: Warheads Design and Terminal Ballistics, Faculty of Mechanical Engineering, Belgrade, 2000.

2. Stamatovic, A.: Projectile design, Ivexy, Belgrade, 1995 (in Serbian)

3. Krsic, N.: Design of fuzes, VINC, Belgrade, 1986 (in Serbian)

4. Elek, P.: Manuscript for lectures, Faculty of Mechanical Engineering, Belgrade, 2010.

number of hours: 45

active teaching (theoretical): 18
lectures: 12
elaboration and examples (revision): 6

active teaching (practical): 18
auditory exercises: 5
laboratory exercises: 0
calculation tasks: 9
seminar works: 2
project design: 0
consultations: 2
discussion and workshop: 0
research: 0

knowledge checks: 9
check and assessment of calculation tasks: 0
check and assessment of lab reports: 0
check and assessment of seminar works: 3
check and assessment of projects: 0
colloquium, with assessment: 3
test, with assessment: 0
final exam: 3

assessment of knowledge (maximum number of points - 100)
feedback during course study: 10
test/colloquium: 30
laboratory exercises: 0
calculation tasks: 0
seminar works: 30
project design: 0
final exam: 30
requirements to take the exam (number of points): 35

references

Backman, M.E.: Terminal Ballistics, NWC China Lake, California, 1976.
Carleone, J.: Tactical Missile Warheads, Progress in Astronautics and Aeronautics, AIAA, Vol. 155, Washington, 1983.
Meyers, M.A.: Dynamic Behavior of Materials, Wiley-Interscience, 1994.
Elek, P., Jaramaz, S.: Penetration models for metal targets ans kinetic penetrators, Cumulative scientifical-technical information, Military Technical Institute, 2005, ISBN 978-86-81123-13-3, pp. 86
Elek, P., Jaramaz, S., Micković, D.: Fragmentation of the case od HE projectiles: Fragment mass distribution laws and physically based fragmentation models, MTI, 2011, ISBN 978-86-81123-23-2, pp.105