

# Goals and Learning Outcomes of Courses in MSc in Mechanical Engineering

## Aerospace Engineering

| position | department            | ID   |            | title                             | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                               |
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| 1.1      | aerospace engineering | 0946 | obligatory | <b>Applied Aerodynamics</b>       | 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. | 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. |
| 1.2      | aerospace engineering | 1078 | obligatory | <b>Computational Aerodynamics</b> | 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 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                                                                             |

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|     |                 |      |          |                          | 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.                                                                                                                                                                                                                                                    | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | 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.                                                                                                                 | 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                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                                   |      |          |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the                                                                                                                                                                                                                                                                                                                                                                                                             | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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|     |                 |      |          |                                   | executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.                                                                                                                                                                                                                                                    | of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 1.5 | thermomechanics | 1375 | elective | <b>Heat and Mass Transfer</b>     | Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering. Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer. | <p>Upon successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.</li> <li>• Explain the heat transfer in semi-infinite bodies.</li> <li>• Perform the heat transfer calculation in semi-infinite bodies.</li> <li>• Apply numerical methods for solving the problems of unsteady heat conduction.</li> <li>• Apply the basic laws of radiation in the in the calculation of radiation of the gas mixture.</li> <li>• Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer.</li> </ul> |
| 1.5 | mathematics     | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                                                                                                                                                                                                                    | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> <li>2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                 |

3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.

4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.

5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | aerospace engineering | 1383 | elective | <b>Rocket Motors</b> | 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. | By mastering the curriculum a student gains specific skills:<br>-knowledge and understanding of rocket motors<br>-calculation of rocket motor performances<br>-design of geometry of propellant grain of solid rocket motor                                                                                                                                        |
| 1.5 | aerospace engineering | 1131 | elective | <b>Helicopters</b>   | 1. Introduction to rotary lifting surface vehicles.<br>2. Introduction to rotor aerodynamic theory.<br>3. Design of helicopters.<br>4. Performance of helicopters.                                                                                                                                                     | 1. Understanding of aerodynamic VTOL schemes.<br>2. Selection of the aerodynamic scheme in helicopter design.<br>3. Mastering theoretical foundations of rotary wing aerodynamics.<br>4. Ability to calculate aerodynamic and performance characteristics of the helicopter.<br>5. Ability to design rotor blade.<br>6. Ability to conceptually design helicopter. |

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|     |                       |      |            |                             | 7. Ability to apply modern software tools in design of helicopters.<br>8. Ability to optimize helicopter design parameters.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 2.1 | aerospace engineering | 0947 | obligatory | <b>Structural Analysis</b>  | <p>1. Introduction to problems and modern calculation methods in stress analysis of aircraft structures, as well as their application to solving real problems.</p> <p>2. Introduction to experimental stress analysis of aircraft structures.</p> <p>3. Introduction to thin walled structures and composite materials.</p> <p>4. Introduction to modern computational methods for stress analysis related to airframe structures.</p> <p>1. Mastering basic structural analysis theories.</p> <p>2. Application of theoretical knowledge to solve practical problems.</p> <p>3. Understanding the basis of aircraft design process.</p> <p>4. Understanding modern methods in structural analysis for stress analysis of aircraft structures.</p>                                                                                                                                                                                                                                                                |
| 2.2 | aerospace engineering | 1472 | obligatory | <b>Flight Dynamics</b>      | <p>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.</p> <p>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.</p> |
| 2.3 | aerospace engineering | 0639 | obligatory | <b>Composite Structures</b> | <p>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</p> <p>1. Starting from the mechanical properties of fibers and matrices to calculate the properties of the composite elastic lamina .</p> <p>2. calculate the load capacity of the composite lamina applying the HILL, Wu and Tsai criteria</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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|     |           |      |          |                                        | <p>structural verification of composite structures.</p> <p>2.Introduction to specifics of thin walled structures and application of composite materials for these structures.</p> <p>3.Introduction to computer simulation and stress analysis of composite structures on aircrafts.</p> | <p>3. Using classical laminate theory (CLT) determine stress strain state in composite laminate for a given external load</p> <p>4. use commercial software for calculation of strength of aircraft composite structures</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 2.4 | mechanics | 0037 | elective | <b>Theory of Mechanical Vibrations</b> | <p>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.</p>                                                              | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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).</li> <li>•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).</li> <li>•Calculate (analytical and numerical) quantities which characterize vibration processes: natural frequencies, amplitudes, phase angles, logarithmic decrements and modal matrix.</li> <li>•Determine equations of motion in analytical form using software (Matlab...) for systems with large number of degrees of freedom.</li> <li>•Describe free undamped mechanical vibrations</li> </ul> |

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.

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| 2.4 | aerospace engineering | 0950 | elective | <b>High Speed Aerodynamics</b> | 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).                                                                                                                                                                                                                                                 | 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.                                                                                                                                                                                                                                                                                                                             |
| 2.4 | aerospace engineering | 1130 | elective | <b>Wind Turbines 2</b>         | 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 | 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). |

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|     |                        |      |          |                                                        | numerical methods.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 2.4 | hydropower engineering | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | <p>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.</p> | <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,</li> <li>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,</li> <li>3. Process and present the measurement results,</li> <li>4. Calculate the measurement uncertainty,</li> <li>5. Explain the calibration of velocity, pressure and flow measuring devices,</li> <li>6. Describe the types and characteristics of sensors.</li> </ol> |
| 2.5 | aerospace engineering  | 0948 | elective | <b>Aircraft Performance</b>                            | <p>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.</p>                                                                                                                                                | <p>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.</p>                                                                                                                                                                                                                                                |

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| 2.5 | aerospace engineering  | 0311 | elective | <b>Avionics</b>                                | 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.                                                                                                                                                                                                                                                                           | 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.                                                                                                                                                                          |
| 2.5 | fluid mechanics        | 1011 | elective | <b>Gas Dynamics</b>                            | The student should:<br>1. acquire basic theoretical knowledge in the field of gas dynamics;<br>2. be trained to perform basic engineering calculations of compressible flows;<br>3. become familiar with the basic procedures for experimental research in gas dynamics.                                                                                                                                                                                                                                                                                 | 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.                                                                                                                                                                                                                                                                                   |
| 2.5 | strength of structures | 0721 | elective | <b>Basics of Composite Materials Mechanics</b> | 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 | 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.<br>2. Students will learn how to perform stress – strain analysis of laminate composite materials.<br>3. The course will devote some attention to the influence of the environmental conditions (e.g. |

properties of composite materials will be tackled as well.

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.

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| 3.1 | aerospace engineering | 1079 | obligatory | <b>Aircraft control and systems</b> | 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.                                                                                                                                                   | 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.                                                                                                                                        |
| 3.2 | aerospace engineering | 1473 | obligatory | <b>Aircraft propulsion</b>          | The main goals of the subject are the students knowledge obtaining of the work principles, types, main elements, characteristics and usage areas of air-breathing engines. One of the principle goal is establishment of the corelation among the aircraft types and appropriate propulsion systems in order to achieve given aircraft mission goal in optimal way according to the goal functions and existing constraints. | Students are going to achieve the ability to perform decomposition, to analyse and to make synthesis of the propulsion system together with the aircraft. The student gets the knowledge of different types of air breathing engines, and their main energetic components. The knowledge obtained by student is related to the design and determining of the performance of the appropriate engines needed for engine quality estimation. Gained knowledge enables further student professional development in the field of aircraft propulsion. |

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| 3.3 | aerospace engineering  | 1132 | obligatory | <b>Aircraft Design</b>                     | <p>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.</p> | <p>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.</p>                                         |
| 3.4 | aerospace engineering  | 1081 | elective   | <b>Aircraft maintenance</b>                | <p>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.</p>                                                                                                                                                                                         | <p>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).</p> |
| 3.4 | general machine design | 1444 | elective   | <b>Technical regulations and standards</b> | <p>Acquiring of the basic knowledge in the field of technical regulations and standards. Fully understanding the mutual</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• the content, significance and types of technical</li> </ul>                                                                                                                                                                                                                                                                                                                 |

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|     |                        |      |          |                                             | 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.                                      | regulations and standards,<br><ul style="list-style-type: none"> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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. | Upon completion of the course syllabus students will be able to: <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul> |

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| 3.4 | aerospace engineering     | 1474 | elective | <b>Project Management &amp; Air Regulation</b>                    | <p>Course objective</p> <ul style="list-style-type: none"> <li>• Understanding the importance of project management in aviation.</li> <li>• The creation, introduction and use of aviation projects.</li> <li>• Determining the functionality of your own projects.</li> <li>• Preparation, analysis and project management.</li> <li>• Understanding and preparing the necessary documents for the implementation of projects.</li> </ul> | <p>The acquired knowledge enables the student to:</p> <ul style="list-style-type: none"> <li>• Prepare, create and show their own skills,</li> <li>• Determine the functionality of the aviation project,</li> <li>• Prepare, perform and manage the development of the aviation project,</li> <li>• Determine technology of designing an aviation project,</li> <li>• Recognize the requirements of the local aviation industry in projects,</li> <li>• Make the necessary documentation of aviation project,</li> <li>• Implement and collect aviation project.</li> </ul> |
| 3.5 | thermal power engineering | 1320 | elective | <b>Computer simulations of thermalhydraulic processes and CFD</b> | <p>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.</p>                                 | <p>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.</p>                                                                                                                                                                                                                                                                                                                             |
| 3.5 | weapon systems            | 1388 | elective | <b>Missile navigation, guidance and control algorithms</b>        | <p>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.</p>                                                                                      | <p>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</p>                                                                                                                  |

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|     |                       |      |          |                                  | 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.                                                                                                                       | 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.                                                                                                                                           |
| 3.5 | aerospace engineering | 1082 | elective | <b>Aircraft armement systems</b> | 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. | By mastering of the course curriculum student obtains following subject - specific skills:<br><br>- thorough knowledge and understanding of different types of aircraft weapons and their application<br>- calculation of air weapons characteristics and possibility of their integration into the aircraft with the use of scientific methods and procedures<br>- linking basic knowledge in mathematics, programming, mechanics and fluid mechanics and their application in design and calculation of aviation weapons and its integration; |
| 3.5 | aerospace engineering | 0645 | elective | <b>Aeroelasticity</b>            | 1. introduction to modern aeroelasticity problems and their analysis and practical methods to solving aeroelasticity problems in real aircraft structures<br>2. introduction to experimental dynamic analysis of aircraft structures<br>3. introduction to dynamics of thin walled structures                                                                                                                                                                           | After successful competition of the course students should be able to:<br><br>1. Determine forms of oscillation of thin walled structure<br>2. calculate the torsional divergence speed of lifting surface<br>3. Calculate the command reversal speed ( ailerons ) on the wings<br>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 .

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| 4.1 | aerospace engineering | 1216 | obligatory | <b>Skill Praxis M - VAZ</b>   | 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.                                                                                                                                                                                                                                                                                                                       | 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.                                                                                                                                                                                                                                 |
| 4.3 | -                     | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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 | Upon the successful completion of M.Sc. Thesis Project, engineers should be able to: <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> </ul> |

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|     |   |      |            |                     | the results.                                                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul> |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | The preparation of M.Sc. 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 thesis. | <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul>                                                                                              |

## Agricultural and Food Engineering

| position | department                  | ID   |            | title                                                     | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
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| 1.1      | agricultural engineering    | 1411 | obligatory | <b>Tractors and self-propelled agricultural machinery</b> | 1. Mastering the theoretical foundations of propulsion machines - tractors and self-propelled agricultural machines - combines;<br>2. Concepts and constructions of agricultural tractors, motor cultivators and self-propelled chassis;<br>3. Transmission and connection systems for working machines and aggregates;<br>4. Concepts of simultaneous power transmission via drive wheels and PTO shafts, energy balance;<br>5. Theory of work, conception and construction of the combine, calculations of the movement of the moving part and technological devices of the combine. | 1. Basic knowledge in the field of theory of work, conception and construction of driving machines - tractors, cultivators and self-propelled chassis and universal self-propelled combines;<br>2. Analysis of mechanical, hydrostatic and combined transmissions of agricultural tractors, self-propelled chassis and universal self-propelled combines;<br>3. Application of computers in calculations of plants and technological devices;<br>4. Connecting basic engineering knowledge and achieving a synergistic effect;<br>5. Acquisition of practical skills and application in practice.<br>Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Manage the procurement of tractors with adequate characteristics according to the available agricultural machinery that the tractor aggregates,</li> <li>• Organize and conduct operation and maintenance of tractors and self-propelled agricultural machines,</li> <li>• Performs and applies solutions of various concepts of tractors and self-propelled chassis,</li> <li>• Make plans for testing tractors,</li> <li>• Determine, formulate and control the ergonomic conditions of the operator.</li> </ul> |
| 1.2      | thermal science engineering | 1544 | obligatory | <b>Refrigeration in Food Technologies</b>                 | Achieving of competence and academic skills as well as methods for their acquisition. The development of creative                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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|     |                 |      |          |                          | 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.                                                                                                                                                                                                                          | consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Reza theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | 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.                                                                                                                 | 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                                                                                                                                                                                                                                                                                                                                                                                                                        |

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|     |                                   |      |          |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.                                                                                                                                                                                 | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> </ul> |

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|     |                          |      |          |                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <ul style="list-style-type: none"> <li>•Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>•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.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 1.5 | industrial engineering   | 0523 | elective | <b>Management Information Systems</b>                                    | 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.                                                                                                                                                                                                 | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Use software tools for decision support,</li> <li>- Design models for decision-making process in DSS tools,</li> <li>- Using expert systems in the field of industrial engineering,</li> <li>- Projected base of knowledge in expert systems,</li> <li>- Estimates of efficiency designed models in the specific case study.</li> </ul>                                                                                                                                                                                                                                                                                          |
| 1.5 | agricultural engineering | 1412 | elective | <b>Microclimate management in agricultural and industrial facilities</b> | The aim of the subject "Microclimate Management in Agricultural and Industrial Facilities" in the Master's degree program at the Faculty of Mechanical Engineering is to provide students with a deep understanding of concepts and the application of methods for managing microclimates in various agricultural and industrial facilities. Through this subject, students are expected to acquire knowledge of methods for determining thermal and mass loads of objects, familiarity with measurement techniques and methods for monitoring environmental parameters, fundamentals | <p>Practical and theoretical knowledge about the processes necessary for organizing and implementing environmental parameter control and the basis of device and control-regulatory systems. Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Recognize and understand the key factors influencing microclimate, including temperature, humidity, lighting, and ventilation.</li> <li>• Apply theoretical knowledge of microclimate management in specific agricultural and industrial facilities, aiming to optimize conditions for plants, animals, or workers.</li> <li>• Identify potential risks associated with microclimatic conditions and develop strategies for</li> </ul> |

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|     |                                               |      |          |                                                              | <p>of calculating required capacities of devices and systems to achieve desired microclimate parameters in agricultural facilities. By the end of the subject, students should be able to design, optimize, and manage microclimates in agricultural and industrial facilities in accordance with the latest standards and best practices.</p> | <p>managing them to minimize negative impacts on production, health, and safety.</p> <ul style="list-style-type: none"> <li>• Utilize the latest technological innovations in microclimate management, such as automated systems for temperature and humidity control, air quality monitoring sensors, and other advanced tools.</li> <li>• Apply principles of sustainable development in the planning and implementation of microclimate control systems.</li> <li>• Effectively communicate and collaborate with various experts in agriculture, industry, engineering, and other relevant disciplines to achieve optimal results in microclimate management.</li> </ul> |
| 1.5 | material handling, construction and logistics | 1539 | elective | <b>Construction, mining and conveying machinery elements</b> | <p>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.</p>                                                          | <p>Goal of this course is to introduce the students to the following skills:</p> <ul style="list-style-type: none"> <li>• Modeling and calculation of unique below-the-hook lifting devices;</li> <li>• Design, modeling and calculations related to fundamental substructures of crawler systems;</li> <li>• Modeling and calculation of bearing structures of mobile construction, transport and mining machines;</li> <li>• Design and calculation of stabilizers;</li> <li>• Computer-aided modeling and creating technical documentation of elements and assemblies of machines used in construction, mining and material handling processes.</li> </ul>               |
| 1.5 | internal combustion engines                   | 1435 | elective | <b>Internal Combustion Engines Fundamentals</b>              | <p>The course provides a comprehensive insight into the matter of the internal combustion (IC) engines (theoretical cycles, actual process, engine systems,</p>                                                                                                                                                                                | <p>Adopted theoretical and practical knowledge in the field of engines. Connecting fundamental disciplines: thermodynamics, fluid mechanics, mechanics, material resistance, etc. on a complex</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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|     |                                   |      |            |                                                                   | operating characteristics). It is intended for students at the Department for IC engines, as an introduction to a deeper study of specific areas of internal combustion engines, as well as students of those fields where knowledge of IC engines as a propulsion unit (motor vehicles, shipbuilding, railway engineering, mechanization) is necessary.                                                                                                   | object such as the internal combustion engine. Acquiring the skills for a competent approach in the selection, organization of operation and maintenance of engines. Acquiring a base for further study of specific problems, construction and design of engines.                                                                                                                                                                                                                                                                                      |
| 2.1 | agricultural engineering          | 1243 | obligatory | <b>Design of agricultural machines and equipment</b>              | 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.                                                                                                                         | After successful completion of this course, studenty should be able to: <ul style="list-style-type: none"> <li>• Define the project management plan,</li> <li>• Define the forces and moments that are plaguing the machines,</li> <li>• Calculation of pressure and dynamic load of agricultural machinery and equipment,</li> <li>• master the methods and processes of agricultural machines and equipment,</li> <li>• Estimates of the outcomes of the project in relation to the initial request,</li> <li>• Be efficient in teamwork.</li> </ul> |
| 2.2 | theory of mechanisms and machines | 1317 | obligatory | <b>Design of mechanisms and manipulators in the food industry</b> | 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 | 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.                 |

food industry.

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| 2.3 | agricultural engineering | 1413 | obligatory | <b>Drying process techniques and technologies</b> | <p>This course provides an in-depth understanding of the various techniques and technologies involved in food drying processes. The course covers the principles and fundamentals of food drying, equipment and facilities for drying, drying methods and techniques, and the quality control of dried foods. The course also covers the application of drying in different food industries, including meat, fruits, vegetables, and grains.</p> | <p>Practical and theoretical knowledge of how to choose the appropriate method of drying agricultural and food materials. Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"><li>• answers to technological requirements for drying agricultural and food materials,</li><li>• select the appropriate drying method,</li><li>• calculate the required capacities and sizes of importance for the selection of basic components of the dryer,</li><li>• independently design the dryer based on the given input parameters of the process.</li></ul>                                                                                                                                                                                                        |
| 2.4 | mechanics                | 0037 | elective   | <b>Theory of Mechanical Vibrations</b>            | <p>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.</p>                                                                                                                                                                                                                      | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"><li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li><li>•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).</li><li>•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).</li><li>•Calculate (analytical and numerical) quantities</li></ul> |

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.

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| 2.4 | motor vehicles | 0451 | elective | <b>Systems Engineering</b> | Course objectives include the achievement of competencies and academic skills as well as methods for their acquisition, in the field of engineering systems. The goals arising from basic tasks and determine the specific results that should be realized within the subject and represent the basis for the control of the results achieved. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Follow and evaluate functional effectiveness of different systems;</li> <li>- Determine methodology for evaluation of system working during their life cycle;</li> <li>- Explain term-system work quality: production and/or service;</li> <li>- Apply different methods and techniques for risk and project management;</li> <li>- Manage costs of life cycle systems;</li> <li>- Explain demands of different series of international standards and ways of their using in different types of organizations;</li> <li>- Connect engineer and manager demands in work processes of different types of organizations;</li> </ul> |
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|     |                                    |      |          |                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | - Adopt and evaluate decisions in conditions of certainty and uncertainty which occurs during system working;                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>                         | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.                                                                                 | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2.4 | production engineering             | 1314 | elective | <b>Additive Manufacturing Technologies</b> | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Recognize the basic differences between methods of material removal, material shaping and adding material (additive technologies)</li> <li>• Distinguish methods of additive manufacturing</li> <li>• Compare methods of additive manufacturing</li> <li>• Analyze the possibility of using additive technologies</li> <li>• Depending on the load of the structure and its purpose, they prescribe the appropriate type if additive technology, as well as modes of manufacturing</li> <li>• Generate a computer model of the work: CAD and scanning</li> <li>• Use generative methods (approaches) of designing based on natural method of construction</li> <li>• Optimize the geometry of the structure according to the conditions of additive technologies</li> <li>• Prepare for manufacturing</li> <li>• Design and calculate a processing system intended for additive</li> </ul> |

manufacturing technologies.

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| 2.5 | general machine design | 1572 | elective | <b>High speed machine design</b>                | The goal of the course is to introduce the students to the design of specific parts and assemblies of the high speed machines.                                                                                                                                                                                                                                                                                                            | Upon successful completion of this course, students should be able to deal with the engineering design of specific parts and assemblies for high speed machine systems. The design methodology implies teaching student to calculate and correctly select bearings, couplings, seals, gears and other machine elements for operation at high speed revolutions. In addition students will have basic knowledge in the field of the design of housing, lubrication, balancing and testing of such systems.                                                                                         |
| 2.5 | industrial engineering | 1370 | elective | <b>Design of logistic and warehouse systems</b> | 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.                                                                   | 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.                                                                                                                                                                                                                                                                                                                      |
| 2.5 | motor vehicles         | 0874 | elective | <b>Vehicles and Environment</b>                 | 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 | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"><li>- Explain the concept of fuel consumption and the possibilities for its reduction;</li><li>- Analyze the impacts of driver on fuel consumption;</li><li>- 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;</li><li>- Identify alternative vehicle drives and fuels;</li><li>- Analyze working principles of hybrid and electric</li></ul> |

vehicles.

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.

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| 2.5 | engineering materials and welding, tribology, fuels and combustion | 0894 | elective | <b>Biofuels in combustion processes</b> | <p>The objective of the course is for the student to:</p> <p>acquire basic knowledge about biomass as fuel and biomass as energy storage; perceive the biomass types and classification; perceive the characteristics of biomass important for application (characterization of biomass - ultimate, proximate and chemical analysis); understand the modern procedures of analysis and characterization; understand the importance of biofuel standardization; perceive solid, liquid and gaseous biofuels (fuels obtained from biomass); perceive the characterization of biofuels; understand processes of thermochemical conversion of biomass (torrefaction, liquefaction, pyrolysis, gasification, combustion), chemical conversion and anaerobic digestion; perceive the advantages and disadvantages of the biomass conversion process; understand the possibilities of using biofuels for energy purposes; perceive the importance of biofuels from the environmental</p> | <p>After successfully passing the exam in this course, the student will be able to:</p> <p>prepare reviews of directives and regulations for the promotion of the use of biomass as a renewable energy source; define the ways of determining and determine the potential of biofuels in the Republic of Serbia; define resources, potentials and characteristics of raw materials for biofuel production; perform comparisons of different types of biofuels; define the most important characteristics of biomass for application; evaluate the potential of different biofuels and their application for different energy technologies; use advanced knowledge on the production of different types of biofuels; perform technical, economic and environmental comparisons of different energy systems that use biofuels; make a comparative analysis of biofuels and fossil fuels; know how to make a critical assessment of logistical issues related to the possibilities of using biofuels in energy systems; make an analysis of the production path of biofuels and determine the most important stages; know how to apply sustainability criteria for different energy systems and evaluate the results of such</p> |
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|     |                          |      |            |                                                                | <p>aspect, understand the production path of biofuels; understand sustainability criteria for biomass and biofuels and verification of sustainability criteria; understand the basics of calculating the combustion process and the emission of polluting substances; review the phases of the combustion process and the basics of modeling; understand modern biofuel combustion systems; acquire knowledge about the possibilities of using mixtures of biofuels and fossil fuels in combustion processes; perceive the strategies of using biofuels for energy purposes and the development of technologies in accordance with world and European policies and regulations.</p> | <p>analysis; make calculations of biofuel combustion and apply appropriate models; perform an analysis, as the next generation of energy users, to predict the consequences of the choice of energy systems.</p>                                                  |
| 3.1 | general machine design   | 1570 | obligatory | <b>Software Tools in Design in Mechanical Engineering</b>      | <p>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).</p>                                                                                                                                                                                                                                                                                                           | <p>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.</p> |
| 3.2 | agricultural engineering | 1244 | obligatory | <b>Geoinformation and remote control of biotechnic systems</b> | <p>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</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <p>After successful completion of this course, studenty should be able to:</p> <ul style="list-style-type: none"> <li>• Identify the different components of the automation system biotechnical,</li> <li>• Define procedures for precision farming,</li> </ul>   |

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|     |                          |      |            |                                                        | 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 dynamic machines and processes in real time                                                                                                                                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• Interpret hydraulic and pneumatic scheme of agricultural machinery,</li> <li>• Projected guidance direction of agricultural machinery,</li> <li>• Organize a complete cycle of precision farming,</li> <li>• Communicate effectively in a multidisciplinary team.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 3.3 | agricultural engineering | 1367 | obligatory | <b>Design of plants and process and energy systems</b> | This course aims to provide students with the necessary knowledge and skills for designing and optimizing facilities and processes in the food production and processing industry. Throughout this course, students should familiarize themselves with various aspects of system design, including production technologies, energy management, quality control, and food safety. By the end of the course, students should be capable of applying the acquired knowledge to solving real-world problems in the field of food production and processing, thus contributing to the improvement and efficiency of these processes in the industry. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Understand the basic principles of designing plants and process systems.</li> <li>• Analyze and evaluate various energy systems in the context of their efficiency and economic viability.</li> <li>• Prepare students to solve project tasks related to designing different plants and systems.</li> <li>• Apply engineering standards and regulations in the process of designing.</li> <li>• Develop teamwork skills through collaborative work on projects.</li> <li>• Understand the impact of system design on the environment and sustainability.</li> <li>• Apply mathematical methods and simulations in the design process.</li> <li>• Develop critical thinking through the analysis of various design alternatives and their consequences.</li> <li>• Improve communication skills through the expression and presentation of design solutions.</li> <li>• Prepare students for a career in the field of design and engineering in energy.</li> </ul> |

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| 3.4 | general machine design | 1444 | elective | <b>Technical regulations and standards</b>  | Acquiring of the 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.                                                                                                                                                                                           | After the attended course, students gain knowledge about: <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                       |
| 3.4 | weapon systems         | 1562 | elective | <b>Hybrid technical systems</b>             | Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical requirements as part of a complex system or the system as a whole</li> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul> |
| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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                                                                                                                                                                                                                                                                                                                        | Upon completion of the course syllabus students will be able to: <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> </ul>                                                                                                                                                                                                                                                                                                                                     |

necessary for successful project management.

- 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.

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| 3.4 | theory of machanisms and machines | 1175 | elective | <b>Food Processing Machines</b> | 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. | 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. |
| 3.5 | thermomechani cs                  | 0924 | elective | <b>Solar energy</b>             | Achieving academic competences in the field of solar energy utilization. Acquiring theoretical and practical knowledge on converting solar into thermal energy,                                                                                                                                                              | Upon successful completion of this course students should be able to: <ul style="list-style-type: none"> <li>• Explain the characteristics of solar radiation at a</li> </ul>                                                                                                                                       |

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|     |                          |      |          |                                                        | acquiring skill of modeling and simulation of processes.                                                                                                                                                                                                                                                                                                                                                                                                              | <p>specific location;</p> <ul style="list-style-type: none"> <li>Analyze energy transport in the elements of the solar thermal systems;</li> <li>Formulate the mass and energy balances for the elements of the solar system (for solar collectors, thermal energy storages, heat exchangers, pipelines);</li> <li>Determine representative energetic characteristics of appropriate elements of the system;</li> <li>Analyze and thermodynamically evaluate the operation of various solar thermal systems.</li> </ul>                                                                                                                                                                                                                                                                           |
| 3.5 | agricultural engineering | 1456 | elective | <b>Plant design for food production and processing</b> | 1. Master the theoretical foundations of the design of machinery, equipment and technological lines for manufacturing and food processing; 2 Getting to know your limitations and the specific production lines and food processing; 3 Introduction to the principles of the design of machinery and equipment manufacturing and food processing; 4 Acquire practical skills in analyzing the set of engineering problems and its solving multidisciplinary approach. | <p>After successful completion of this course, studenty should be able to:</p> <ul style="list-style-type: none"> <li>Define the project management plan,</li> <li>Describe the production technology and food processing,</li> <li>Select the appropriate machinery and equipment for the design of complete lines and factories for processing agricultural products,</li> <li>Design complete line and / or factory for the production, processing and storage of agricultural products,</li> <li>Estimates of the outcomes of the project in relation to the initial request,</li> <li>Estimates energy required for food processing,</li> <li>Be efficient in teamwork,</li> <li>Estimates of economic analysis,</li> <li>Preparing and exposing projects to potential investors.</li> </ul> |
| 3.5 | thermal power            | 1320 | elective | <b>Computer</b>                                        | The aim is acquiring knowledge and skills                                                                                                                                                                                                                                                                                                                                                                                                                             | The students are trained to perform computer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

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|     | engineering              |      |            | <b>simulations of thermalhydraulic processes and CFD</b> | 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.                                                                                                               | 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.                                                                                                                                                                                                                                                                                                                                                                                                   |
| 4.1 | agricultural engineering | 1530 | obligatory | <b>Skill Praxis M - PPM</b>                              | 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.                                                                                                                                                      | 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 poznavstva that will be able to use at school or entering into future employment.                                                              |
| 4.3 | -                        | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                            | Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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 | Upon the successful completion of M.Sc. Thesis Project, engineers should be able to: <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> </ul> |

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|     |   |      |            | information technologies for analysis and synthesis of technological systems; implementing standard tests and measuring and providing an overview of the results. | <ul style="list-style-type: none"> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>         |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b>                                                                                                                                               | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Biomedical Engineering

| position | department                         | ID   |            | title                                           | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
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| 1.1      | biomedical engineering             | 1398 | obligatory | <b>Spectroscopy methods and techniques</b>      | 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 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. | Upon successful completion of this course, students will be able to: <ul style="list-style-type: none"> <li>•Use different measurement instruments and methods of UV-Vis / NIR and FTIR spectroscopy</li> <li>•Work in the laboratory and perform characterization of materials using appropriately selected spectroscopic methods</li> <li>•Determine composition, as well as the chemical and physical properties of the tested materials</li> <li>•Perform multivariate spectral analysis using computer software packages</li> </ul> |
| 1.2      | physics and electrical engineering | 1323 | obligatory | <b>Biomedical instrumentation and equipment</b> | 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 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.                                                                                                                                                                                                     |

educates engineers to work together with other experts to improve existing and develop new biomedical equipment.

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| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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.</p>                            |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic</li> </ul> |

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|     |                                   |      |          |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <p>phenomena using Reza theorem.</p> <ul style="list-style-type: none"> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.</p> <p>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p>                                                                                                                                                                          | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> </ul> |

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|     |                                    |      |          |                                   |                                                                                                                                                                                                                                                                                                                                                                     | <ul style="list-style-type: none"> <li>•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.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b>         | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines. | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;</li> <li>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;</li> <li>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;</li> <li>4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.</li> </ol> <p>Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.</p> <p>Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.</p> |
| 1.5 | mathematics                        | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                                                                                                         | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.

3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.

4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.

5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | biomedical engineering | 1278 | elective | <b>Fractal mechanics</b> | <p>The goal of this subject is to teach a student to apply fractal and multi-fractal system theory in a field of biomedical engineering; to learn to use mathematical apparatus of fractal analysis and modelling; to master fractal image processing and fractal signal analysis; to learn to define diagnostic parameters, algorithms and instruments for determining functional conditions of organs and organism (normal conditions and pathological conditions).</p> | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Assess whether the objects have fractal properties and describe the fractal behavior of the systems by properly chosen method of fractal analysis</li> <li>•Create fractal algorithms for image analysis and signal analysis</li> <li>•Perform calculation of the fractal dimension using modern methods</li> <li>•Define diagnostic parameters for determining the functional states of tissues, organs and organism based on fractal dimension</li> </ul> |
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| 2.1 | biomedical engineering | 1283 | obligatory | <b>Clinical Engineering</b> | <p>To enable practical implementation, in real life clinical conditions, of theoretical knowledge and R&amp;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.</p> <p>Introduction to design and maintenance of medical equipment (chirurgical tables, beds, chairs, etc.).</p> <p>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</p> | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Apply gamma camera, PET and ultrasound in medicine</li> <li>•Perform surface electrical stimulation of small intensity and activation of afferent system - artificial perception (in the laboratory)</li> <li>•Perform measurements of evoked potentials induced by transcranial magnetic stimulation and measurement of temperature distribution (in the laboratory).</li> <li>•Prepare all necessary documents for obtaining ethical permission for clinical work</li> <li>•Prepare all necessary documents for obtaining a license to use a new instrument in the clinic.</li> <li>•Distinguish and define the basic principles of diagnostic devices (biochemical analyzer - ECG - Rò device)</li> <li>•Develop applications for the STM32 microcontroller for adequately defined applications</li> </ul> |
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|     |                        |      |            |                                          | design medical devices based on STM 32, ARM, microcontrollers.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2.2 | biomedical engineering | 1399 | obligatory | <b>Introduction to nanotechnology</b>    | <p>The objective of this course is to provide students with a fundamental understanding of the physics of nanostructures and nanotechnology. Through theoretical lectures and practical exercises, students will gain knowledge about the basic types and characteristics of nanomaterials and nanoparticles, methods and techniques for their synthesis and characterization, as well as the applications and implications of nanotechnology in various industries. Additionally, students will analyze the ethical, environmental, and societal aspects of nanotechnology, enabling them to critically consider the role of nanotechnology in modern society.</p> | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>- Understand the basic concepts and principles of the physics of nanostructures and nanotechnology</li> <li>- Establish the difference between physical and biological processes at the nano level, as well as micro and macro system</li> <li>- Identify various types of nanomaterials and their specific properties</li> <li>- Establish the difference and define the basic principles of devices used for the characterization of nanomaterials</li> </ul>                                                                                       |
| 2.2 | mechanics              | 0559 | obligatory | <b>Biomechanics of tissue and organs</b> | <p>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</p>                                                                                                                                  | <ul style="list-style-type: none"> <li>•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)</li> <li>• Identify the most important rheological properties of considered HTO</li> <li>• Distinguish between (Kelvin-Voigt, Maxwell model, Standard linear solid (SLS) model) on the basis of the linear theory of viscoelasticity (LTV)</li> <li>• Forming the appropriate rheological models HTO applying LTE in time and frequency domain</li> <li>• Numerical simulate the previously formed</li> </ul> |

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|     |                        |      |            |                            | specialized clinical institutions.                                                                                                                                                                                                                                                                                                                                                                                                                                                  | rheological models using programming environment (MATLAB, etc.).<br>• Identify the properties and characteristics of non-linear and plastic behavior considered HTO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 2.3 | biomedical engineering | 1343 | obligatory | <b>Signal Processing</b>   | Introduction to basic concepts and knowledge related to continuous-time and discrete-time signals, deterministic and stochastic signals, signal processing and analysis in time and frequency domain, digital filter design. Introduction to the specific nature of the biomedical signals, mainly electrophysiological signals, and various approaches to biomedical signal processing and analysis. Mastering digital signal processing methods and its application using MATLAB. | Upon successful completion of this course, students shall be able to:<br>• Apply MATLAB software for the analysis and processing of the major electrophysiological time series<br>• Form and implement program for signal acquisition and properly choose acquisition system parameters depending on the type of biomedical signal<br>• Master the application and the characteristics of Fourier transform and Z-transform<br>• Distinguish characteristics of different biomedical signals (EEG, ECG, EMG) in time and frequency domain<br>• Select and apply different filtering methods depending on the characteristics of the signal being processed and the types of further applications of such signals<br>• Form a user interface for signal processing and displaying, adequately present time series and signal processing results in the time, frequency and time-frequency domain. |
| 2.4 | mechanics              | 0007 | elective   | <b>Mechanics of robots</b> | 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                                                                                                                                                                                                                                               | • Determine the number of degrees of freedom of robotic system (RS)<br>• Define the matrix of transformation, in the case of (Euler angles, Reza angles, Hamilton-Rodrigues parameters, ...)<br>• Forming expressions to determine the basic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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.

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

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| 2.4 | production engineering             | 1536 | elective | <b>Mechatronics Systems</b> | <p>The goal of the course in mechatronic systems is to provide a focused interdisciplinary theoretical knowledge and practical experience for students that encompass fundamental elements from traditional courses in mechanical engineering, production engineering, electronics and computer control engineering.</p>                                                                                                  | <p>After successfully completing the course, student is capable to:</p> <ol style="list-style-type: none"> <li>1. Analyze project task referring to production processes and define concept of mechatronic system using multi-disciplinary approach;</li> <li>2. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with digital input-output signals;</li> <li>3. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with analog and mixed input-output signals;</li> <li>4. Configure hardware and input-output channels and other system resources of an integrated microprocessor system, create application software for serial communication with the digital environment, including serial communication with a personal computer;</li> </ol> |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>          | <p>Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.</p> | <p>Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

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| 2.4 | internal combustion engines | 1478 | elective | <b>Sensors and Computer Based Measurements</b>    | <p>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 to the world of virtual instrumentation and graphical programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in functioning and using DAQ systems through numerous, real-world examples. To get closer acquaintance with the sensors, and digital acquisition software &amp; hardware, in general, and methods of DACQ software development and testing.</p> | <p>Ability to integrate sensors and DAQ hardware in measurement chains in order to fulfill specific requirements in the field of mechanical engineering system testing &amp; measurements. Ability to build and test software applications (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 the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.</p>                                                                    |
| 2.5 | production engineering      | 1107 | elective | <b>New generation of machine tools and robots</b> | <ol style="list-style-type: none"> <li>1. Perception of different levels of the new generation of machine tools and robots concept.</li> <li>2. Acquisition of basics of reconfigurable, high-speed, meso- and micro-machines and highaccuracy machine tools.</li> <li>3. Practical knowledge about parallel kinematic machines and machines for material addition processes and multi-axis machining.</li> <li>4. Development of programming skills relevant for the new generation of machine tools and robots.</li> <li>5. Development of report-making skills.</li> </ol>                                                                                                        | <p>After completed this course the students should be able to:</p> <ul style="list-style-type: none"> <li>•Understand the role, importance, types and applications of the new generation of machine tools and robots.</li> <li>•Understand different levels of the new generation of machine tools and robots concept.</li> <li>•Select appropriate new generation machine tools and robots for given technological task.</li> <li>•Select and prepare environment for operation of machine tools and robots.</li> <li>•Programming the new generation of machine tools and robots.</li> <li>•Use new programming methods for numerically controlled systems.</li> </ul> |

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| 2.5 | engineering materials and welding, tribology, fuels and combustion | 1337 | elective | <b>Biomaterials in Medicine and Dentistry</b>             | Introducing students to the application of different biomaterials, previously discussed during Foundations of Biomaterials course, in order to understand and study functional behaviour of biomaterials in the human body. Analysis of the connections between the biomaterial and the body system, in order to ensure reliable implant operation. The potential co-operation with experts in the field of materials science, dentistry and medicine is allowed, which provides the ability to work in specialized laboratories and clinical facilities. | By attending this course the student will master the application of biomaterials in medicine and dentistry, using modern scientific methods. Theoretical considerations, laboratory experimental work and the application of numerical analysis using the licensed software for finite element method, enables the synergy of the previously acquired knowledge in physics, materials science, mathematics and mechanics, in order to implement them in engineering practice.                                                                                                                                                                                                              |
| 2.5 | information technologies                                           | 1494 | elective | <b>Embedded systems and IoT in mechanical engineering</b> | Acquisition of theoretical and practical knowledge in the field of embedded systems and Internet of Things.                                                                                                                                                                                                                                                                                                                                                                                                                                               | Students are trained for practical work with embedded systems in the Internet environment. Students have theoretical knowledge of Internet architecture and embedded systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 2.5 | strength of structures                                             | 0721 | elective | <b>Basics of Composite Materials Mechanics</b>            | 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                                     | <ol style="list-style-type: none"> <li>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.</li> <li>2. Students will learn how to perform stress – strain analysis of laminate composite materials.</li> <li>3. The course will devote some attention to the</li> </ol> |

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|     |                        |      |            |                          | the characterization of mechanical properties of composite materials will be tackled as well.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 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.<br>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.                                                                                                                                                                     |
| 3.1 | biomedical engineering | 1282 | obligatory | <b>Nanotechnology</b>    | Goal of this subject is for students to acquire knowledges of: electron tunnelling phenomena, molecular attractive and repulsive forces, nanomaterials, conversion and transport of energy on nanoscale level. Introduction of basic methods, techniques and devices for characterisation of nanomaterials: Scanning NanoProbe microscopy and spectroscopy. Nano electrochemical cell. Characterisation of conductive, magnetic and non-conductive materials: inorganic as well as biological. Nano films: characterisation and modification of sample surfaces by STM/AFM/MFM methods. | Upon successful completion of this course, students will be able to:<br><br><ul style="list-style-type: none"> <li>•Distinguish between the basic components and principles of electron tunneling as well as the basic components and principles of attraction-repulsion effects</li> <li>•Apply basic theoretical and experimental knowledge to analyze nano system</li> <li>•Work on devices for characterization of nanomaterials, STM and AFM</li> <li>•Carry out appropriate preparation of various samples for the scanning probe microscopy</li> <li>•Performs characterization of materials at the nano level</li> <li>•Apply acquired knowledge of software analysis of graphical and analytical data obtained by scanning probe microscopy</li> </ul> |
| 3.2 | biomedical             | 1342 | obligatory | <b>Early Diagnostics</b> | The goal of this course is to introduce                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Upon successful completion of this course, students                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

engineering

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.

shall be able to:

- Understand principles of medical diagnostic devices
- Understand methods of medical image forming across various medical imaging modalities
- Perform measurements using Optomagnetic imaging spectroscopy in the early diagnostics of cancer
- Propose and define the appropriate hardware and software solutions for existing devices for early diagnostics in terms of improvement
- To write and present scientific work in accordance with the standards of professional quality

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| 3.3 | biomedical engineering | 1400 | obligatory | <b>Nanomedical Engineering</b>     | Student will get knowledge of nanoscience and 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. | Upon successful completion of this course, students will be able to: <ul style="list-style-type: none"><li>• Distinguish principles of operation and the specific conditions of application of the devices in the field of nanotechnology in medicine</li><li>• Recognize the advantages of new medical devices in the field of nanotechnology as opposed to solutions in classical medical devices</li><li>• Give suggestions of modification of technical solutions in nanotechnologies with a review to their effective application in medicine</li><li>• Write and present scientific work in accordance with the standards of professional quality and in quality equal to the works published in professional journals</li></ul> |
| 3.4 | biomedical engineering | 1344 | elective   | <b>Information Technologies in</b> | Introducing students with fundamental principles of applied information                                                                                                                                                                                                                                                                                                                                                                                                       | Upon successful completion of this course, students shall be able to:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

## Medicine

technologies in medicine, with a goal of examining the important characteristics of implementations of new technologies in medicine. Simulation of realistic problems and specific requirements for implementation of logical structures in hospitals, telediagnosics, national and global healthcare information systems.

- Distinguish different branches of software engineering, as well as to differentiate which part of the Information System covers which branch of software engineering
- Define the specifics of medical information systems and ways of their design
- Apply the acquired knowledge to create models of simple and medium complexity of medical information systems
- Adequately analyze the requirements for the creation of an information system for a given problem
- Create a set of models that define a medical information system
- Create the necessary documentation and models for the development-construction of medical information systems

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| 3.4 | strength of structures | 1575 | elective | <b>Finite element method in structural</b> | <p>The scope of this course is to provide a thorough theoretical and practical foundation for Finite Element Method (FEM). In the first part of the course the students will become familiar with the application of FEM to the solution of boundary value problems in elasticity. The formulation of weak form of the solution will be in the main focus, regarding problems of statics and dynamics of simpler structures. The main goal of this part of the course is to give a full and detailed view of the development of linearized formulation for diverse structural problems, by employing displacement based FEM. The matrix</p> | <p>Upon fulfilling the course the students will be able to:</p> <ol style="list-style-type: none"><li>1. Write their own computer codes for building stiffness matrix by employing finite elements of truss type, beam type as well as continuum finite elements in 2D and 3D.</li><li>2. Write their own computer codes in order to perform static and dynamic finite element analysis of simpler structures.</li><li>3. Write their own computer codes for post-processing of resulting displacement values in nodal points, in order to recover strains and stresses.</li><li>4. Understand the foundation on which commercial FEM software are build.</li></ol> |
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formulation of the problem will be presented in details. While the main focus is on methodology applied through coding in various computer codes, the students will also learn the basics of use of diverse commercial software.

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| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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. | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul> |
| 3.4 | fluid mechanics        | 1559 | elective | <b>Computational</b>                        | Student should gain basic theoretical                                                                                                                                                                                                                             | Upon successful completion of the course, students                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Fluid Dynamics (CFD)**

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.

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

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3.5

fluid mechanics

0940

elective

**Microfluidics and Nanofluidics**

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.

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;
- apply 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.

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| 3.5 | fluid mechanics | 1382 | elective | <b>Multiphase flow</b> | <p>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.</p> | <p>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-</p> |
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|     |                        |      |          |                                                                   | hydraulic lift. An important part of learning outcomes is learning about different modes of transport, selecting and calculating separators.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 3.5 | industrial engineering | 0520 | elective | <b>Man - machine system design</b>                                | <p>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.</p> <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Identify the main types of mechanical hazards</li> <li>• Carry out the selection and to apply the basic types of safety protections on machines</li> <li>• Perform the identification of all other types of hazards in the working environment and to implement hazard analysis in a man - machine system</li> <li>• Apply basic procedures for hazard prevention</li> <li>• To realize the complete program for realization of safe products within the organization</li> <li>• Identify different types of errors in the man - machine system and to apply appropriate solutions aimed at eliminating errors</li> <li>• Conduct an ergonomic evaluation of design solutions of manuals</li> <li>• Design technical and project documentation in accordance with the ergonomic recommendations</li> </ul> |
| 3.5 | industrial engineering | 1458 | elective | <b>Improving the quality of business processes - Lean 6 Sigma</b> | <p>The aim of the course is to acquaint students with modern approaches and methods for improving the quality of production processes, using Lean management approaches and the Six Sigma methodology, and students to be able to apply the aforementioned tools.</p> <p>Upon completion of the course, students are able to: 1. Understand the concept of Lean - resource-saving production. 2. Understand Lean tools and capacity utilization, including Kaizen and Gemba procedures. 3. They understand and apply quality control methods in production, including the Six Sigma methodology. 4. They understand the basics of integrating the Lean concept and the Six Sigma methodology. 5. They master the methodology of</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

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|     |                        |      |            |                               | experiment design, which includes the method of setting up, conducting the experiment and realizing the analysis and post-analysis of the modern approach of statistical design of experiments, including the interpretation of regression and correlation analysis.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 4.1 | biomedical engineering | 1345 | obligatory | <b>Skill Praxis M - BMI</b>   | <p>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.</p> <p>With mastering the course program, students get familiar with: 1. clinic's organizational processes and problems 2. functioning and maintenance of instruments for measurements, apparatus, and devices for diagnostics and therapy 3. instrumentation, apparatus, and device maintenance.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 4.3 | -                      | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct,</li> </ul> |

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|     |   |      |            |                     | analyse and interpret the results;<br>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;<br>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;<br>• Consider different solutions critically and self-critically;<br>• Apply the acquired knowledge in practice;<br>• Adapt to newly arising situations in practice.                                                                                                                                                                                                                                                                                                               |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Control Engineering

| position | department          | ID   |            | title                    | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
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| 1.1      | control engineering | 1554 | obligatory | <b>Computer control</b>  | 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. "Offline" use of MATLAB as software standard of automatic control.                                                        | Exact but not approximate treatment of CCS according to their discrete nature. Scientific and engineering treatment of CCS as dominantly represented in practice. Applying the methods of analysis and synthesis of a controller in CCS, as well of whole CCS. Solving problems of calculation nature by means of computer and MATLAB in the "offline" mode, related to the analysis or synthesis of CCS. Determining of dynamic and static characteristics of CCS.                                                                                                                                          |
| 1.2      | control engineering | 0286 | obligatory | <b>Automatic Control</b> | <ul style="list-style-type: none"> <li>• 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.</li> <li>• to include all the issues which usually listens worldwide at a course of control</li> <li>• to enable students to follow the following subjects in this Department</li> </ul> | <ul style="list-style-type: none"> <li>• The acquisition of wider knowledge of the automatic control, as a technical field that requires a modern engineer</li> <li>• identify and use the methods needed for analysis and synthesis of controllers in the control systems, and the entire control systems</li> <li>• the implementation of computers and MATLAB and address the underlying problems of the automatic control, as well as other engineering problems</li> <li>• the analytical and / or experimental investigation of the basic dynamic and static characteristics of the systems</li> </ul> |
| 1.3      | mechanics           | 0004 | elective   | <b>Mechanics M</b>       | 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,                                                                                                                                                                                                                                                                                                                | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with</li> </ul>                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                                   |      |          |                          | <p>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.</p>                                             | <p>one degree of freedom.</p> <ul style="list-style-type: none"> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul>                                       |
| 1.3 | fluid mechanics                   | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p> | <p>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.</p> |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>      | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control</p>                                                                                                                                                       | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

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|     |                        |      |          |                         | module, and the work algorithm.<br>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.                                                                                                                                                                                                                                                                                                                                       | mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 1.4 | thermomechanics        | 0202 | elective | <b>Thermodynamics M</b> | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |
| 1.5 | hydropower engineering | 1423 | elective | <b>Pumps and fans</b>   | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid.                                                                                                                                                                                                                                                                                                                                                                                                                   | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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|     |                                    |      |          |                           | Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.                                                                                                                                                                                                           | energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                                                                                                                                                                                                                                                       |
| 1.5 | information technologies           | 1303 | elective | <b>Computer Networks</b>  | <p>Course objective:</p> <ul style="list-style-type: none"> <li>• Introduction to the concept, standard tasks and operation of computer networks.</li> <li>• 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.</li> </ul>                    | <p>The acquired knowledge allows students:</p> <ul style="list-style-type: none"> <li>• to identify and suggest the type of computer network,</li> <li>• to understand the problems that arise whendesigning computer networks,</li> <li>• to create a project of computer network that includes a sugestion purchase of necessary equipment.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b> | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines. | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;</li> <li>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;</li> <li>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;</li> <li>4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform</li> </ol> |

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|     |                             |      |            |                                                                 | elementary diagnostics of possible failures of electrical machines.<br>Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.<br>Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.                                                                                                                                                                                                                                                                                                                        |
| 1.5 | thermal science engineering | 1256 | elective   | <b>Central Heating Systems</b>                                  | <p>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.</p> <p>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.</p> |
| 2.1 | control engineering         | 1555 | obligatory | <b>Dynamic systems modelling, identification and simulation</b> | <p>For the student to learn the basic principles and stages of mathematical modeling and identification of dynamic systems of various natures. For the student to master working with the Matlab, Simulink, Simscape simulation packages.</p> <p>Getting to know, accept and master the basic principles of mathematical modeling in the sphere of electrical, mechanical, electromechanical, fluid and thermal processes. Acquiring knowledge for verification of mathematical models of dynamic systems experimentally and identification of parameters of mathematical models by working on a computer using the Matlab and Simulink packages.</p>      |
| 2.2 | control engineering         | 0628 | obligatory | <b>Nonlinear Systems 1</b>                                      | <ul style="list-style-type: none"> <li>• Introduction to nonlinearities in the plants and processes.</li> <li>• Introduction to basic concepts of analysis of nonlinear systems.</li> <li>• Understanding and using the basic tools for testing the stability of nonlinear</li> </ul> <p>On successful completion of the course the students should be able to:<br/>Knowledge and understanding of:</p> <ul style="list-style-type: none"> <li>• Recognize and understand nonlinear problems and phenomena in the processes and plants.</li> <li>• Determine mathematical models of nonlinear</li> </ul>                                                   |

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|     |                     |      |            |                                        | systems.<br>• Analysis of nonlinear systems using Matlab/Simulink programming software.                                                                                                                                                                                                                                                                          | systems.<br>• Apply basic methods for analyzing nonlinear systems in time domain and state space.<br>• Perform simulations, analysis and control of nonlinear systems using software package Matlab/Simulink.                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 2.3 | control engineering | 1556 | obligatory | <b>Synthesis of linear systems</b>     | For the student to know the basic requirements when designing an automatic control system, first of all in the form of knowing the basic indicators of the system's operation, both in a stationary state and in transient operating modes. For the participant to get to know a wide range of modern methods for designing realistic automatic control systems. | To get to know, accept and master some of the offered methods for designing automatic control systems and to be trained to implement them on each specific example from the class of studied systems. What is more expected is the application of automatic control system design methods that take place in real time on objects and processes and for classes of linear systems with feedback.                                                                                                                                                                                                                                                                               |
| 2.4 | mechanics           | 0037 | elective   | <b>Theory of Mechanical Vibrations</b> | 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.                                                                                                                                             | Upon successful completion of this course, students will be able to:<br><br>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.<br>•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).<br>•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.

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| 2.4 | mechanics | 0007 | elective | <b>Mechanics of robots</b> | <p>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.</p> | <ul style="list-style-type: none"><li>• Determine the number of degrees of freedom of robotic system (RS)</li><li>• Define the matrix of transformation, in the case of (Euler angles, Reza angles, Hamilton-Rodrigues parameters, ...)</li><li>• 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</li><li>• Forming a kinematic model RS and solve direct and inverse kinematics task of RS</li></ul> |
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- 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

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| 2.4 | hydropower engineering | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | 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 | On successful completion of this course, students should be able to:<br>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,<br>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and |
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|     |                                    |      |          |                              | 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.                                                                | contemporary measuring techniques,<br>3. Process and present the measurement results,<br>4. Calculate the measurement uncertainty,<br>5. Explain the calibration of velocity, pressure and flow measuring devices,<br>6. Describe the types and characteristics of sensors.                                                                                                                                                                                                                                               |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>           | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design. | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                                                                                        |
| 2.5 | control engineering                | 0599 | elective | <b>Industrial Automation</b> | 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.                                                                                                                                                              | 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. |

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|     |                           |      |          |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Student is able to create HMI project with operators panel.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2.5 | production engineering    | 0722 | elective | <b>Computer Simulation in Manufacturing Automation</b> | 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. | <p>After successfully completing this course, the students should be capable to:</p> <ul style="list-style-type: none"> <li>- Create and implement stochastic simulation;</li> <li>- Create conceptual model for discrete event simulation;</li> <li>- Create and implement discrete event simulation within fixed and flexible automation framework;</li> <li>- Create conceptual and computer model for continuous simulation of various processes;</li> <li>- Integrate continuous and discrete event simulation;</li> <li>- Manage discrete event simulation project.</li> </ul> |
| 2.5 | thermal power engineering | 1499 | elective | <b>Thermal Turbomachinery</b>                          | <ol style="list-style-type: none"> <li>1. The achievement of academic competence in the field of steam and gas turbines and thermal power engineering.</li> <li>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).</li> <li>3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam and gas turbines.</li> <li>4. The achievement of the techniques of</li> </ol>                                                   | <ol style="list-style-type: none"> <li>1. Academic deep knowledge of the thermodynamic cycle and flows in steam and gas turbines and turbine plants</li> <li>2. The development of critical thinking about energy use, fuel efficiency and environmental preservation</li> <li>3. The ability of calculate heat balance diagrams and main parameters of the steam and gas turbine power plants.</li> <li>4. Ability to use computer technology for modeling and calculations</li> </ol>                                                                                              |

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|     |                        |      |            |                                                   | process modeling.<br>5. Mastering the methods of experimental work in thermal power engineering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 2.5 | production engineering | 1107 | elective   | <b>New generation of machine tools and robots</b> | <ol style="list-style-type: none"> <li>1. Perception of different levels of the new generation of machine tools and robots concept.</li> <li>2. Acquisition of basics of reconfigurable, high-speed, meso- and micro-machines and highaccuracy machine tools.</li> <li>3. Practical knowledge about parallel kinematic machines and machines for material addition processes and multi-axis machining.</li> <li>4. Development of programming skills relevant for the new generation of machine tools and robots.</li> <li>5. Development of report-making skills.</li> </ol> | <p>After completed this course the students should be able to:</p> <ul style="list-style-type: none"> <li>• Understand the role, importance, types and applications of the new generation of machine tools and robots.</li> <li>• Understand different levels of the new generation of machine tools and robots concept.</li> <li>• Select appropriate new generation machine tools and robots for given technological task.</li> <li>• Select and prepare environment for operation of machine tools and robots.</li> <li>• Programming the new generation of machine tools and robots.</li> <li>• Use new programming methods for numerically controlled systems.</li> </ul> |
| 3.1 | control engineering    | 0642 | obligatory | <b>Fuzzy Control Systems</b>                      | <ul style="list-style-type: none"> <li>• Understanding of fuzzy approach to modeling phenomenon, process and systems.</li> <li>• Introduction to basic of fuzzy set theory and fuzzy control theory.</li> <li>• Introduce students to the fundamental principles of artificial neural networks.</li> <li>• Analysis, design, simulation and practical realization of fuzzy control systems using Matlab/Simulink programming software.</li> </ul>                                                                                                                             | <p>On successful completion of the course the students should be able to:</p> <ul style="list-style-type: none"> <li>• Understand fuzzy set, fuzzy logic and fuzzy control theory.</li> <li>• Design of fuzzy controllers and fuzzy systems.</li> <li>• Realize of various fuzzy control algorithms.</li> <li>• Perform simulation and practically implement various fuzzy control systems using PC and programing software Matlab/Simulink.</li> </ul>                                                                                                                                                                                                                        |
| 3.2 | control engineering    | 1380 | obligatory | <b>Industrial process control</b>                 | To introduce students to methods of design and realization of control systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | The acquired knowledge is used in engineering practice. The student is competent to understand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

|     |                        |      |            |                                             |                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
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|     |                        |      |            |                                             | and real time control.                                                                                                                                                                                                                                                                | electrohydraulic and electromechanical servosystems and implementation of simple solutions.<br>The student is able to implement and tune control algorithms in real time. The student is able to commission servo drive and frequency controller.                                                                                                                                                                                                                                                                                                                                                    |
| 3.3 | control engineering    | 0609 | obligatory | <b>Nonlinear Systems 2</b>                  | <ul style="list-style-type: none"> <li>• Building the foundations of nonlinear control design and analysis.</li> <li>• Introducing commonly used nonlinear control tools.</li> <li>• Analysis and control of nonlinear systems using Matlab/Simulink programming software.</li> </ul> | <p>On successful completion of the course the students should be able to:</p> <ul style="list-style-type: none"> <li>• Perform basis of dynamical analysis of certain classes of nonlinear systems.</li> <li>• Apply various methods for testing the system stability by Lyapunov techniques and input-output analysis.</li> <li>• Understand and use different control techniques of nonlinear systems.</li> <li>• Perform simulations, analysis and control of nonlinear systems using software package Matlab/Simulink.</li> </ul>                                                                |
| 3.4 | industrial engineering | 1248 | elective   | <b>Techno-economic analysis and project</b> | 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.                     | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> </ul> |

|     |                        |      |          |                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
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|     |                        |      |          |                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <ul style="list-style-type: none"> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul>                                                                                                                                                                                                                                                                           |
| 3.4 | hydropower engineering | 0928 | elective | <b>Renewable energy resources - small hydropower plants</b> | <p>Achieving academic competence in the field of small hydropower plants, hydromechanical equipment and hydro energy.</p> <p>Obtaining practical knowledge in small hydropower plants designing and the content of the technical project documentation.</p> <p>Mastering knowledge of how to choose and calculate hydromechanical equipment installed in small hydroelectric stations.</p> <p>Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.</p> <p>Improving individual creative abilities in performing professional design of small</p> | <p>On successful completion of this course the students will be able to:</p> <ul style="list-style-type: none"> <li>- define, plan and organize the phases of project design, build up and operation of small hydropower plants,</li> <li>- 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,</li> <li>- check the adopted geometry and operating characteristics by basic analysis of the transient operating regimes and water hammer phenomenon,</li> <li>- collect, analyze and present the calculation results,</li> <li>- choose the best solution to the specific case by analyzing more possible solutions from the point of energy efficiency,</li> <li>- work as a part of a team as well as demonstrate their entrepreneurial skills.</li> </ul> |

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| 3.4 | weapon systems            | 1562 | elective | <b>Hybrid technical systems</b>    | Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical requirements as part of a complex system or the system as a whole</li> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul>                                                                                                         |
| 3.4 | control engineering       | 0657 | elective | <b>Intelligent Control Systems</b> | <ul style="list-style-type: none"> <li>• Introduction to methods for the analysis and design of intelligent control systems.</li> <li>• Gaining practical knowledge of several of the main techniques of intelligent control and an introduction to some promising research directions.</li> <li>• Use of the computer for simulation and evaluation intelligent control systems.</li> </ul>                                                                                                                                                | On successful completion of the course the students should be able to: <ul style="list-style-type: none"> <li>• Understand of the functional operation of a variety of intelligent control techniques.</li> <li>• Understand of control-theoretic foundations.</li> <li>• Carry out synthesis and analysis of intelligent control systems based on combinations of various theories: simulation, neural networks, fuzzy systems, genetic algorithms, biologically inspired algorithms, etc.</li> <li>• Use of the computer for simulation and evaluation intelligent control systems through Matlab/Simulink software, as and practical realization of control algorithms on various control plants using programming software Matlab.</li> </ul> |
| 3.5 | thermal power engineering | 0336 | elective | <b>Turbocompressors</b>            | 1. The achievement of academic competence in the field of compressors                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | On completion of this programme, it is expected that student will be able to:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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|     |                        |      |          |                              | <p>and thermal power plant engineering.</p> <p>2. Mastery of theoretical knowledge about how to transform mechanical work into internal energy of fluid by learning of thermodynamic processes and equipment.</p> <p>3. The acquisition of practical skills for design and optimization of turbocompressors.</p> <p>4. Mastering the techniques of process modeling.</p> | <ul style="list-style-type: none"> <li>• perform design of a multistage axial compressor writing own program code,</li> <li>• select dimensionless parameters of compressor stages,</li> <li>• apply one-dimensional theory of the compressor stage, determine the main dimensions of the stage, calculate efficiency and the stage operating parameters,</li> <li>• apply the appropriate solutions of 3D flow and define 3D blade geometry of the compressor stage</li> <li>• select the type of aero profile, calculate the aerodynamic losses and deviation</li> <li>• define the meridian flow path of the entire machine</li> <li>• apply different control modes for the turbocompressor</li> <li>• analyse compressor behavior at off-design operating parameters.</li> </ul> |
| 3.5 | control engineering    | 0656 | elective | <b>Intelligent Buildings</b> | To introduce students to the concept of intelligent buildings, technical systems in modern buildings and control systems technology and their integration.                                                                                                                                                                                                               | <p>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.</p> <p>Student is able to create ETS project and program KNX components.</p> <p>Student is able to make application schematics of HVAC system, to define signal list and define quote of sensors, actuators and controllers.</p>                                                                                                                                                                                                                                                                                            |
| 3.5 | hydropower engineering | 1423 | elective | <b>Pumps and fans</b>        | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid.                                                                                                                                                                                                                                                        | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

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|     |                     |      |            |                                                            | Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 3.5 | weapon systems      | 1388 | elective   | <b>Missile navigation, guidance and control algorithms</b> | 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. | 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 sensors 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. |
| 4.1 | control engineering | 1557 | obligatory | <b>Skill Praxis M - SAU</b>                                | Practical experience and students 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 design,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Students obtain practical experience on how 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|     |   |      |            | development and production, as well as the roles and tasks of mechanical engineering in such a business system. | business information flows. Student identifies the core processes in the design, manufacture, maintenance, in the context of his future professional competence. Establish the personal contacts and relationships that will be able to use at school or entering into future employment.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                                                                                   | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> </ul> |

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|     |   |      |            |                     | <ul style="list-style-type: none"> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Design in Mechanical Engineering

| position | department                | ID   |            | title                                                 | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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| 1.1      | general<br>machine design | 1098 | obligatory | <b>Structure<br/>Modelling with<br/>Calculation</b>   | <p>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.</p> <p>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 of this modification is to get an optimum shape that allow us to achieve optimal solutions in machine design modeling.</p> | <p>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.</p> |
| 1.2      | general<br>machine design | 1302 | obligatory | <b>Innovative<br/>Design of<br/>Technical Systems</b> | <p>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</p>                                                                                                                                                                                                                                                                                                                                          | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Abstract thinking in the innovative creation (design) of a technical system.</li> <li>• Manage the process of searching for ideas and design solutions.</li> <li>• Create a conceptual structure (new operating principle) of a technical system based on the developed function structure.</li> <li>• Raise the level of properties of technical systems</li> </ul>                                                                                                                                                                                   |

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|     |                 |      |          |                          | 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.            | in functional, aesthetic, ecological, market and other environmental conditions.<br>• Develop innovative technical solutions based on the transformation of biological systems, software and mental functions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | 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. | Upon successful completion of this course, students should be able to:<br>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.<br>• Analyze the motion of variable mass particle.<br>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.<br>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.<br>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.<br>• Solve problems related to the impact (collision) of a particle and rigid body. |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | Main goal is to learn student general principles of fluid mechanics and how to apply them in solving practical engineering problems. In that sense                                                                                                                                                                                                                                                                             | 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

proper understanding of general laws and equations is necessary. This will also enable student to develop further in other topics based on fluid mechanics.

(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.

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| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• Recognize and determine the thermodynamic properties of wet gases and implement them in the</li> </ul> |
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|     |                                               |      |          |                                                              |                                                                                                                                                                                                                                                                                                                                                        | analysis of thermomechanical processes in devices and facilities with moist air.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.4 | theory of mechanisms and machines             | 1150 | elective | <b>Mechatronics</b>                                          | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.<br>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements. | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                 |
| 1.5 | material handling, construction and logistics | 1539 | elective | <b>Construction, mining and conveying machinery elements</b> | 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.                                                                         | Goal of this course is to introduce the students to the following skills:<br><ul style="list-style-type: none"> <li>•Modeling and calculation of unique below-the-hook lifting devices;</li> <li>•Design, modeling and calculations related to fundamental substructures of crawler systems;</li> <li>•Modeling and calculation of bearing structures of mobile construction, transport and mining machines;</li> <li>•Design and calculation of stabilizers;</li> <li>•Computer-aided modeling and creating technical documentation of elements and assemblies of machines used in construction, mining and material handling processes.</li> </ul> |
| 1.5 | physics and electrical engineering            | 0401 | elective | <b>Electric Machinery</b>                                    | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power                                                                                | Upon successful completion of this course, students should be able to:<br>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;<br>2) adequate mathematical express and quantify different physical quantities that describe the                                                                                                                                                                                                                                                                                                                                   |

engineering. The students will meet during the course different types of electric machines.

operation of electrical machines;  
 3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;  
 4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.  
 Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.  
 Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

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| 1.5 | general machine design | 1483 | elective   | <b>Practicum in engineering design basics</b> | Introduction to the engineering design basics for typical machine parts, elements and assemblies. Application of basic previously acquired knowledge and skills for the design of machine parts, elements and assemblies (computer graphics, material technology, machine elements calculations, production technology). Preparation of technical documentation. Generating fundamentals for higher levels of complex machine systems design and product development. | At the end of this course, the student should be able to:<br>- recognise and explain the construction of machine parts, elements and assemblies (from the aspect of material technology, manufacturing and assembly technology, and application);<br>- to apply basic knowledge about the dominant influences on construction (static strength, dynamic durability, stiffness, load-bearing capacity, service life, reliability, technological aspects, economic aspects, user needs, market requirements) in the design of machine parts, elements and assemblies;<br>- to create construction documentation and instructions for installation, use and maintenance. |
| 2.1 | industrial engineering | 1041 | obligatory | <b>Ergonomic design</b>                       | Students should acquire specific practical skills that include an integrated ergonomic approach for the design of a                                                                                                                                                                                                                                                                                                                                                   | Upon successful completion of this course, students should be able to:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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.

- 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

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| 2.1 | aerospace engineering | 1471 | obligatory | <b>Bionics in design</b> | 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, | 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. |
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|     |                        |      |            |                                          | dimensions and shape of machine parts, alignment features (functional and aesthetic) with the environment, living and working environment.                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 2.2 | general machine design | 1441 | obligatory | <b>Machine Design and Construction M</b> | 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.                                       | <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• Through the design stages they will be able to select the optimum variant design from technological and economic point of view - Techno-economic analysis,</li> <li>• Applying technical directives and regulations in the machine design and putting the product on the market,</li> <li>• Evaluate the operational capacity of pressed joints,</li> <li>• Resolves advanced problems with measuring chains,</li> <li>• Check capacity of thin and thick-walled pressure vessels from strength point of view,</li> <li>• Make a selection of welded joints in terms of mutual position of the parts to be joined,</li> <li>• To form and do the technical documentation of given mechanical construction.</li> </ul> |
| 2.3 | production engineering | 0302 | obligatory | <b>Decision-making methods</b>           | 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 | <p>Students' learning outcomes of this course are:</p> <ul style="list-style-type: none"> <li>• The complex use of IC technologies in decision-making.</li> <li>• 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.</li> <li>• Autonomous selection of the methods based on</li> </ul>                                                                                                                                                                                                                                                                                                                                                                     |

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|     |                             |      |          |                                                | conceptual design points out the optimum decision function based on intelligent agents.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <p>application of artificial neural networks and genetic algorithms in seeking the optimal solution in the process of product development.</p> <ul style="list-style-type: none"> <li>• 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.</li> <li>• Capability for team work.</li> </ul>                                                                                                                                       |
| 2.4 | internal combustion engines | 1478 | elective | <b>Sensors and Computer Based Measurements</b> | <p>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 to the world of virtual instrumentation and graphical programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in functioning and using DAQ systems through numerous, real-world examples. To get closer acquaintance with the sensors, and digital acquisition software &amp; hardware, in general, and methods of DACQ software development and testing.</p> | <p>Ability to integrate sensors and DAQ hardware in measurement chains in order to fulfill specific requirements in the field of mechanical engineering system testing &amp; measurements. Ability to build and test software applications (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 the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.</p> |
| 2.4 | mechanics                   | 0037 | elective | <b>Theory of Mechanical Vibrations</b>         | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>• Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> </ul>                                                                                                                                                                                                                                                                                                                                                            |

- 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.

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| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b> | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration |
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|     |                        |      |          |                                                | and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.                                                                                                                                                                                                                                | of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 2.4 | production engineering | 1314 | elective | <b>Additive Manufacturing Technologies</b>     | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Recognize the basic differences between methods of material removal, material shaping and adding material (additive technologies)</li> <li>• Distinguish methods of additive manufacturing</li> <li>• Compare methods of additive manufacturing</li> <li>• Analyze the possibility of using additive technologies</li> <li>• Depending on the load of the structure and its purpose, they prescribe the appropriate type if additive technology, as well as modes of manufacturing</li> <li>• Generate a computer model of the work: CAD and scanning</li> <li>• Use generative methods (approaches) of designing based on natural method of construction</li> <li>• Optimize the geometry of the structure according to the conditions of additive technologies</li> <li>• Prepare for manufacturing</li> <li>• Design and calculate a processing system intended for additive manufacturing technologies.</li> </ul> |
| 2.5 | strength of structures | 0721 | elective | <b>Basics of Composite Materials Mechanics</b> | 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                                                                                                                                                                                                                                                                     | 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

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.

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.

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| 2.5 | general machine design | 1572 | elective | <b>High speed machine design</b>  | The goal of the course is to introduce the students to the design of specific parts and assemblies of the high speed machines. | Upon successful completion of this course, students should be able to deal with the engineering design of specific parts and assemblies for high speed machine systems. The design methodology implies teaching student to calculate and correctly select bearings, couplings, seals, gears and other machine elements for operation at high speed revolutions. In addition students will have basic knowledge in the field of the design of housing, lubrication, balancing and testing of such systems. |
| 2.5 | material handling,     | 1540 | elective | <b>Design of construction and</b> | Basic course goals (objectives): 1) introducing students to specificity of                                                     | This course offers the following skill set to the students who complete it:                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|     | constructios<br>and logistics |      |            | <b>mining machines<br/>subsystems</b>                                 | 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.                                                                                                                             | <ul style="list-style-type: none"> <li>•Design of backhoe excavators' working devices;</li> <li>•Design of basic elements of single-bucket excavators' working devices;</li> <li>•Modeling and calculation of a bucket wheel excavator's working device – bucket wheel body and buckets;</li> <li>•Design and calculation of the bucket wheel drive system;</li> <li>•Design and calculation of four and eight-wheel bogie of a crawler mechanism;</li> <li>•Calculation of basic technical and technological parameters, power and strength of jaw and conic rock crushers;</li> <li>•Load analysis, modeling, proper supporting, loading and finite element analysis of civil and mining machines' fundamental subassemblies.</li> </ul> |
| 3.1 | general<br>machine design     | 1570 | obligatory | <b>Software Tools in<br/>Design in<br/>Mechanical<br/>Engineering</b> | 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). | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 3.2 | information<br>technologies   | 1449 | obligatory | <b>Optimization<br/>Methods</b>                                       | <p>The main goal of this course for the student is to give the necessary knowledge of:</p> <ul style="list-style-type: none"> <li>• numerical analysis and optimization,</li> <li>• understanding general principles of design optimization</li> </ul>                                                                                                             | <p>After completing this course students are able to successfully apply the acquired theoretical and practical knowledge and are able to:</p> <ul style="list-style-type: none"> <li>•Identify relevant optimization variables, define the set of functional constraints and limitations for the corresponding optimization model of a given</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                                                |      |            |                                              | <ul style="list-style-type: none"> <li>• formulating the optimization problems and identify critical elements.</li> </ul>                                                                                                                                                                                                                                                                                                                                        | <p>mechanical system.</p> <ul style="list-style-type: none"> <li>•Apply linear and non-linear numerical methods for solving the optimization problems and define the appropriate convergence criteria.</li> <li>•Develop and implement computer programs in software packages Python / MATLAB for solving the set of optimization tasks.</li> <li>•Analyze the results and check the validity of the proposed optimization models with respect to the change of input parameters.</li> <li>•Apply the stochastic - heuristic methods and develop hybridized heuristic methods to determine the global solution of the optimization problems of complex mechanical systems.</li> <li>•Develop new and apply existing numerical methods for solving complex optimization tasks, individually or as part of an appropriate team.</li> </ul> |
| 3.3 | material handling, constructions and logistics | 0127 | obligatory | <b>Eco Design</b>                            | 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. | <p>By completing this course student acquires ability to:</p> <ul style="list-style-type: none"> <li>•analyse life cycle of a product using tools for life cycle assessment</li> <li>•implement ecodesign strategies into design process and product development</li> <li>•suggest measures for improvement of environmental performances of the product</li> <li>•implement legislative in the field of ecology into design process</li> <li>•design and develop sustainable product</li> </ul>                                                                                                                                                                                                                                                                                                                                         |
| 3.4 | information technologies                       | 1496 | elective   | <b>Computer Graphics and Virtual Reality</b> | Introduction to the study of the basic principles of computer graphics, elementary and complex                                                                                                                                                                                                                                                                                                                                                                   | <p>After successful completion of the program provided by this subject student can:</p> <ul style="list-style-type: none"> <li>• apply the acquired knowledge in the scientific,</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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|     |                        |      |          |                                            | 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. | technical and engineering applications of virtual reality technology,<br><ul style="list-style-type: none"> <li>• to design engineering software based on computer graphics,</li> <li>• to integrate knowledge in the field of video game physicality.</li> </ul>                                                                                                                                                                                                   |
| 3.4 | general machine design | 1444 | elective | <b>Technical regulations and standards</b> | Acquiring of the 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.                                                                                 | After the attended course, students gain knowledge about: <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul> |
| 3.4 | weapon systems         | 1562 | elective | <b>Hybrid technical systems</b>            | Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed                             | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical requirements as part of a complex system or the</li> </ul>               |

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|     |                        |      |          |                                                 | general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | system as a whole<br><ul style="list-style-type: none"> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 3.4 | production engineering | 1535 | elective | <b>Assembly Technology</b>                      | <ol style="list-style-type: none"> <li>1. Learning of systematic approach to the design and production of mechanical assemblies;</li> <li>2. Understanding assembly process and basic assembly operations;</li> <li>3. Impact of assembly process on product development – product structure and Design For Assembly techniques;</li> <li>4. Part mating process, modeling and understanding relationships between precision, sensitivity and flexibility;</li> <li>5. Basic concepts of assembly systems – manual, automatic and robotic systems; Assembly system design; Assembly workstation design issues;</li> <li>6. Performance and Economics of Assembly Systems;</li> <li>7. Product lifecycle and product disassembly.</li> </ol> | <p>After successfully completing course, student is capable to:</p> <ol style="list-style-type: none"> <li>1. Analyze assembly and carry out its optimal sequencing into basic assembly operations for the given set of criteria;</li> <li>2. Design a system for automatic assembly that includes parts feeding, orientation, separation and geometry control;</li> <li>3. Design systems for manual assembly with all sub-systems including sequencing;</li> <li>4. Design systems for automatic and robotized assembly including work stations, as well as peripherals for parts feeding;</li> <li>5. Optimize assembly design with respect to its assemblability using qualitative and quantitative Design for Assembly techniques</li> </ol> |
| 3.5 | production engineering | 0601 | elective | <b>Micro Manufacturing and Characterization</b> | 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                                                                                                                                                                                                                                                                                                                                                                                                                      | <p>At the end of this course students will be able to:</p> <p>Apply basic principles of manufacturing in the micron area</p> <p>Identify the different machine and tools, industrial robots, assembly and transport systems and automation systems applicable to micro manufacturing</p> <p>Select the suitable methods of micro manufacturing</p>                                                                                                                                                                                                                                                                                                                                                                                                |

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|     |                                                                    |      |          |                              | <p>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.</p>                                                                                                                                                                                                                                                                           | <p>according to techno-economic criteria.<br/> Select the principle of measurement and characterization of functional primitives<br/> Understanding the properties of the material adequate for micro manufacturing.<br/> Apply scientific methods of analysis, synthesis and design, as well as computer technology</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 3.5 | engineering materials and welding, tribology, fuels and combustion | 0537 | elective | <b>Tribological systems</b>  | <p>The student attending this course should:</p> <ul style="list-style-type: none"> <li>• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);</li> <li>• Master the calculation methods for tribological elements using the modern lubrication theories;</li> <li>• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.</li> </ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"> <li>• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;</li> <li>• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;</li> <li>• Propose the solutions for problems originate from the friction and wear process;</li> <li>• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;</li> <li>• Applies methods for the calculation of working and tribological characteristics of considered tribological system;</li> <li>• Select materials, lubricants and lubrication mode for the considered tribological systems.</li> </ul> |
| 3.5 | control engineering                                                | 0656 | elective | <b>Intelligent Buildings</b> | <p>To introduce students to the concept of intelligent buildings, technical systems in modern buildings and control systems technology and their integration.</p>                                                                                                                                                                                                                                                                                                                                                              | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                        |      |            |                               | <p>Student is able to create ETS project and program KNX components.</p> <p>Student is able to make application schematics of HVAC system, to define signal list and define quote of sensors, actuators and controllers.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 4.1 | general machine design | 1571 | obligatory | <b>Skill Praxis M - DUM</b>   | <p>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.</p> <p>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.</p> <ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- The models of communication and flows in the development and implementation of product and market realization.</li> <li>- In recognition of the basic processes in engineering design, manufacture and maintenance of TS.</li> </ul> |
| 4.3 | -                      | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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,</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> </ul>                                                                                                                                                                                                                                                                                                                                                                  |

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|     |   |      |            | 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. | <ul style="list-style-type: none"> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul> |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b>                                                                                                                                                                                                                                                                      | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul>                                                                                                                                              |

## Engineering graphics and mechatronics

| position | department                        | ID   |            | title                                                 | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------|-----------------------------------|------|------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.1      | theory of mechanisms and machines | 1507 | obligatory | <b>Constructive processing of curves and surfaces</b> | The goal is for students to learn the basic geometric characteristics and invariants of plane and spatial curves, as well as surfaces important for mechanical engineering. The goal is also for students to master both theoretical and concrete, practical methods of generation and constructive processing of the mentioned types of curves and surfaces. Practical methods include the generation and processing of curves and surfaces by direct sketching and drawing procedures, as well as advanced methods that are implemented using appropriate computer tools (SolidWorks). | The outcome of the course is the acquisition of knowledge that can be applied in the generation and constructive processing of selected types of curves and surfaces that are used for designing and 3D modeling of various objects in the practice of mechanical engineering. By mastering this subject, students are trained to efficiently design and generate complex machine parts and assemblies.                                                           |
| 1.2      | theory of mechanisms and machines | 1508 | obligatory | <b>Constructive geometry and graphics</b>             | To renew the basics of Constructive geometry and graphics and to enrich the already existing knowledge with new material that is necessary for students of mechanical engineering, and it was not possible to cover it due to the small number of classes in undergraduate studies. For students to acquire advanced knowledge and skills of design, constructive processing and rendering of objects in three-dimensional space in all types of projections.                                                                                                                            | Acquisition of new and advanced knowledge from various fields of constructive geometry and their application in mechanical engineering. Essential understanding of positional and metrical invariants of three-dimensional space in all types of projections. Students are trained to creatively use constructive procedures of shaping, processing and rendering of spatial forms and solve complex positional and metrical problems of three-dimensional space. |
| 1.3      | mechanics                         | 0004 | elective   | <b>Mechanics M</b>                                    | The aim of this course is that students                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Upon successful completion of this course, students                                                                                                                                                                                                                                                                                                                                                                                                               |

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|     |                 |      |          |                          | <p>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.</p> | <p>should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Reza theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                         | <p>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.</p>                                                                                                |
| 1.4 | theory of       | 1150 | elective | <b>Mechatronics</b>      | <p>Mastering the knowledge fund required</p>                                                                                                                                                                                                                                                                                                                                                  | <p>Possessing the engineering capabilities to perform a</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

mechanisms  
and machines

for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.

qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.

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| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"><li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li><li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li><li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li><li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li><li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li><li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li><li>• 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.</li></ul> |
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| 1.5 | general machine design                        | 1483 | elective | <b>Practicum in engineering design basics</b>                | Introduction to the engineering design basics for typical machine parts, elements and assemblies. Application of basic previously acquired knowledge and skills for the design of machine parts, elements and assemblies (computer graphics, material technology, machine elements calculations, production technology). Preparation of technical documentation. Generating fundamentals for higher levels of complex machine systems design and product development. | At the end of this course, the student should be able to:<br>- recognise and explain the construction of machine parts, elements and assemblies (from the aspect of material technology, manufacturing and assembly technology, and application);<br>- to apply basic knowledge about the dominant influences on construction (static strength, dynamic durability, stiffness, load-bearing capacity, service life, reliability, technological aspects, economic aspects, user needs, market requirements) in the design of machine parts, elements and assemblies;<br>- to create construction documentation and instructions for installation, use and maintenance. |
| 1.5 | material handling, construction and logistics | 1539 | elective | <b>Construction, mining and conveying machinery elements</b> | 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.                                                                                                                                                                                        | Goal of this course is to introduce the students to the following skills:<br>•Modeling and calculation of unique below-the-hook lifting devices;<br>•Design, modeling and calculations related to fundamental substructures of crawler systems;<br>•Modeling and calculation of bearing structures of mobile construction, transport and mining machines;<br>•Design and calculation of stabilizers;<br>•Computer-aided modeling and creating technical documentation of elements and assemblies of machines used in construction, mining and material handling processes.                                                                                            |
| 1.5 | physics and electrical engineering            | 0401 | elective | <b>Electric Machinery</b>                                    | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important                                                                                                                                                                                                                                                                                                              | Upon successful completion of this course, students should be able to:<br>1) adequately recognize, mathematically describe and understand the most important types of                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines.

electrical machinery and processes in them;  
 2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;  
 3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;  
 4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.  
 Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.  
 Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

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| 1.5 | industrial engineering            | 0523 | elective   | <b>Management Information Systems</b>   | 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. | Upon successful completion of this course, students should be able to:<br>- Use software tools for decision support,<br>- Design models for decision-making process in DSS tools,<br>- Using expert systems in the field of industrial engineering,<br>- Projected base of knowledge in expert systems,<br>- Estimates of efficiency designed models in the specific case study. |
| 2.1 | theory of machanisms and machines | 0989 | obligatory | <b>Engineering Condition Monitoring</b> | Students are to acquire necessary knowledge to trouble-shoot the machinery, reveal main cause of malfunction and prescribe remedial                                                                                                                                                                                                                                                   | 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                                                                                                                                                                                           |

|     |                                   |      |            |                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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|     |                                   |      |            |                                                       | action. Introduction of equipment and devices for engineering diagnosis and skills development for applying them.                                                                                                                                                                                                                                                                                                                                                                                     | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2.2 | theory of machanisms and machines | 1509 | obligatory | <b>Fundaments of mechanism analysis and synthesis</b> | <p>Acquiring knowledge and mastering the basic skills of analysis and synthesis of mechanisms. Study of structural, kinematic, and dynamic analysis of mechanisms, on the basis of which the analysis and synthesis of planar and spatial mechanisms are carried out. Familiarity with various software packages used in the field of mechanism analysis and synthesis.</p> <p>Application of theoretical knowledge acquired in the subjects Mechanics 2 (Kinematics) and Mechanics 3 (Dynamics).</p> | The student has mastered the theoretical foundations for a complete structural, kinematic, and dynamic analysis of mechanisms. By using these basics and solving problems of analysis (calculated and using software tools), the student is able to determine the elements necessary for the synthesis of mechanisms. Then, using different methodologies, and mathematical and software tools, the student is able to perform a synthesis of planar and spatial mechanisms. Also, on a concrete example, within the assigned project, the student masters the skill of independently creating a specific mechanism. According to the studied course, students are trained to perform analysis, modeling, synthesis, and generation of mechanisms in various software packages. |
| 2.3 | theory of machanisms and machines | 1510 | obligatory | <b>Applied mechatronics</b>                           | The goal of the course is to equip the student with the knowledge needed to solve a mechatronic problem. That is, to develop the ability to devise a mechatronic solution for a classic mechanical problem. Selection of sensors for a mechatronic solution. That choice must satisfy the given criteria: principle of operation (optical, ultrasonic, magnetic...), dimensionally to fit into the overall solution, sending signals (voltage/current, communication). Drive                          | For the student to come up with a conceptual solution for the mechatronic system. To choose the appropriate drive, sensors and finally control.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

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|     |                        |      |          |                                            | selection: electric motor (tesla motor, direct current motors, servo motors...); pneumatic cylinder/motor; hydraulic cylinder/motor. And finally, the choice of control body: PC, PLC, microcontroller.                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 2.4 | production engineering | 1536 | elective | <b>Mechatronics Systems</b>                | The goal of the course in mechatronic systems is to provide a focused interdisciplinary theoretical knowledge and practical experience for students that encompass fundamental elements from traditional courses in mechanical engineering, production engineering, electronics and computer control engineering. | <p>After successfully completing the course, student is capable to:</p> <ol style="list-style-type: none"> <li>1. Analyze project task referring to production processes and define concept of mechatronic system using multi-disciplinary approach;</li> <li>2. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with digital input-output signals;</li> <li>3. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with analog and mixed input-output signals;</li> <li>4. Configure hardware and input-output channels and other system resources of an integrated microprocessor system, create application software for serial communication with the digital environment, including serial communication with a personal computer;</li> </ol> |
| 2.4 | production engineering | 1314 | elective | <b>Additive Manufacturing Technologies</b> | 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                                                                                                              | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Recognize the basic differences between methods of material removal, material shaping and adding material (additive technologies)</li> <li>• Distinguish methods of additive manufacturing •</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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|     |                          |      |          |                                                      | 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.                                                                                                                                                                                | 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. |
| 2.4 | information technologies | 1448 | elective | <b>Distributed Systems in Mechanical Engineering</b> | <ul style="list-style-type: none"> <li>• Introduction to the paradigm of distributing data</li> <li>• Knowledge of basic protocols for the transfer and sharing of distributed data.</li> <li>• Designing local area networks based on different technologies</li> <li>• Introduction to multiprocessor distributed systems in the automotive and aircraft industry</li> <li>• Introduction to algorithms that are typical of multi-processor distributed systems</li> </ul> | <p>Стечено знање омогућава студенту:</p> <ul style="list-style-type: none"> <li>• to recognize the conditions for the formation of local area networks</li> <li>• to allocate names to resources on the net</li> <li>• to control and manage assigned resources</li> <li>• to understand the multi-processor and redistribution of data among them</li> </ul>                                                                                                                                                                                                                                                                          |
| 2.5 | general machine design   | 1572 | elective | <b>High speed machine design</b>                     | The goal of the course is to introduce the students to the design of specific parts and assemblies of the high speed machines.                                                                                                                                                                                                                                                                                                                                               | Upon successful completion of this course, students should be able to deal with the engineering design of specific parts and assemblies for high speed machine systems. The design methodology implies teaching student to calculate and correctly select bearings, couplings, seals, gears and other machine                                                                                                                                                                                                                                                                                                                          |

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|     |                                   |      |            |                                                           | elements for operation at high speed revolutions. In addition students will have basic knowledge in the field of the design of housing, lubrication, balancing and testing of such systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 2.5 | industrial engineering            | 1370 | elective   | <b>Design of logistic and warehouse systems</b>           | <p>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.</p> <p>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.</p>                                                                                                                                                                                    |
| 2.5 | information technologies          | 1494 | elective   | <b>Embedded systems and IoT in mechanical engineering</b> | <p>Acquisition of theoretical and practical knowledge in the field of embedded systems and Internet of Things.</p> <p>Students are trained for practical work with embedded systems in the Internet environment. Students have theoretical knowledge of Internet architecture and embedded systems.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 3.1 | theory of mechanisms and machines | 1511 | obligatory | <b>Engineering graphics and simulations</b>               | <ul style="list-style-type: none"> <li>• introducing students to the problems of advanced modeling of more complex machine parts and assemblies, as well as their presentation in the appropriate technical documentation</li> <li>• gaining insight into different types of technical documentation used in mechanical engineering</li> <li>• basic training for creating appropriate simulations of parts and assemblies</li> </ul> <p>After completing the course, students acquire the necessary knowledge for modeling more complex machine parts, assembling them into a functional assembly, simulating that assembly in order to check the appropriate characteristics, creating technical documentation, analyzing the data obtained by simulation and creating an animation that shows the working process of the appropriate assembly.</p> |
| 3.2 | theory of mechanisms and machines | 1512 | obligatory | <b>Application of virtual and augmented</b>               | <p>Mastery of knowledge in the field of Virtual Reality (VR) and Augmented Reality (AR). Introduction to modern ways</p> <p>The student successfully familiarized himself with existing solutions and trends in the field of VR/AR. He mastered the skills necessary to adapt existing</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

**reality in  
mechanical  
engineering**

of graphic communication and information transfer within the field of mechanical engineering, both between engineering teams and between other participants in the industrial production process. Introduction to existing hardware and software solutions (Head Mounted Displays (HMD), VR/AR tracking systems, VR/AR software). Application of engineering knowledge acquired at previous levels of studies and their implementation in VR/AR systems, development of 3D models of parts and assemblies with the necessary technical data displayed directly on the 3D models, development and design of prototypes, and application of VR/AR in maintenance and repair of machine assemblies.

communication methods in the field of mechanical engineering (technical documentation) to the specificities of VR/AR. Also, students acquired the necessary knowledge and mastered various software packages necessary for the preparation of 3D models adapted for VR/AR.

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| 3.3 | theory of mechanisms and machines | 1513 | obligatory | <b>The aesthetics of 3d modeling</b> | <p>Acquisition of basic theoretical knowledge about the criteria of aesthetics in the process of designing and constructing products. Acquisition of theoretical and practical knowledge in 3D modeling, modification of existing models to improve aesthetics and/or functionality. Familiarizing students with the laws of aesthetics in the process of product design; recognition of subjective and objective factors in the formation of aesthetic judgement; treatment of aesthetic elements and principles; use of classical and modern means for creating aesthetic properties; familiarization with</p> | <p>After completing this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• They actively use 3D tools for modeling the conceptual product,</li> <li>• Independently analyze the product and make corrections to improve aesthetics and/or functionality</li> <li>• Creatively use abstract elements and principles of aesthetics,</li> <li>• They creatively use practical (classical and contemporary) means to create the aesthetic properties of the product</li> </ul> |
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|     |                                   |      |          |                                 | the characteristics of modern graphic signs and aesthetic properties of packaging and advertising; the importance of the effect of product aesthetics on the process of modeling, constructing, manufacturing, and finally advertising and marketing.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 3.4 | production engineering            | 1535 | elective | <b>Assembly Technology</b>      | <ol style="list-style-type: none"> <li>1. Learning of systematic approach to the design and production of mechanical assemblies;</li> <li>2. Understanding assembly process and basic assembly operations;</li> <li>3. Impact of assembly process on product development – product structure and Design For Assembly techniques;</li> <li>4. Part mating process, modeling and understanding relationships between precision, sensitivity and flexibility;</li> <li>5. Basic concepts of assembly systems – manual, automatic and robotic systems; Assembly system design; Assembly workstation design issues;</li> <li>6. Performance and Economics of Assembly Systems;</li> <li>7. Product lifecycle and product disassembly.</li> </ol> | <p>After successfully completing course, student is capable to:</p> <ol style="list-style-type: none"> <li>1. Analyze assembly and carry out its optimal sequencing into basic assembly operations for the given set of criteria;</li> <li>2. Design a system for automatic assembly that includes parts feeding, orientation, separation and geometry control;</li> <li>3. Design systems for manual assembly with all sub-systems including sequencing;</li> <li>4. Design systems for automatic and robotized assembly including work stations, as well as peripherals for parts feeding;</li> <li>5. Optimize assembly design with respect to its assemblability using qualitative and quantitative Design for Assembly techniques</li> </ol> |
| 3.4 | theory of mechanisms and machines | 1175 | elective | <b>Food Processing Machines</b> | <ol style="list-style-type: none"> <li>1. Getting acquainted with the basic concepts necessary for dealing with matter in this field.</li> <li>2. Acquiring skills in preparation of modern design programs for designing and analyzing the operation of food equipment and plants.</li> <li>3.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                  | <ol style="list-style-type: none"> <li>1. Knowledge and understanding of the problem of food machines</li> <li>2. Analyzing existing solutions and their effects</li> <li>3. Linking knowledge from various fields of technology, tracking the newspapers and applying them</li> <li>4. Adopting practical knowledge</li> <li>5. Solving concrete problems in the production of</li> </ol>                                                                                                                                                                                                                                                                                                                                                        |

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|     |                        |      |          |                                             | Developing students' creative abilities to design food systems, machines and systems.                                                                                                                                                                                                                                                             | food machines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 3.4 | general machine design | 1444 | elective | <b>Technical regulations and standards</b>  | Acquiring of the 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. | After the attended course, students gain knowledge about: <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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.                                                                                 | Upon completion of the course syllabus students will be able to: <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human</li> </ul> |

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|     |                                                  |      |          |                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p>resource management, risk management and procurement on the project,</p> <ul style="list-style-type: none"> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul>                                                                                                                              |
| 3.5 | industrial engineering                           | 1418 | elective | <b>Appraisal of Projects in IT field</b> | <p>Understanding the importance of the process of planning, evaluating and evaluating projects in the field of information technology. Introduction to different methodological approaches for the analysis of IT / IS projects. Mastering sophisticated techniques of financial and economic analysis as well as standard techniques for managing IT / IS projects. Mastering techniques and routines for identifying and monetary quantification of difficult to detect costs and effects implied by the implementation of IT / IS projects.</p> | <p>After completing the course the student should: identify the project idea, prepare a database with all costs and effects of IT / IS projects, calculate criteria for selection of project alternatives, gain knowledge and routines for recognizing difficult costs and effects of IT / IS projects, organize networks project resource flow activities with the choice of optimal paths and minimum costs and assess the uncertainty and risk of IT / IS projects.</p> |
| 3.5 | process and environmental protection engineering | 0997 | elective | <b>Technical legislation</b>             | <p>Objective of the course is that students acquire academic skills and academic competencies for application of technical legislation. Through teaching activities, students acquire creative and specific practical skills that qualify them to work in their professional field - design.</p>                                                                                                                                                                                                                                                   | <p>By successful completion of the study program student acquires the following skills: analysis, synthesis and prediction of solutions and consequences; development of critical thinking and self-critical approach; application of knowledge in practice; professional ethics; correlation of knowledge from different fields and their applications; development of skill and proficiency in the use of knowledge in field of technical documentation preparation.</p> |

|     |                        |      |          |                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| 3.5 | industrial engineering | 0520 | elective | <b>Man - machine system design</b>                                | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Identify the main types of mechanical hazards</li> <li>• Carry out the selection and to apply the basic types of safety protections on machines</li> <li>• Perform the identification of all other types of hazards in the working environment and to implement hazard analysis in a man - machine system</li> <li>• Apply basic procedures for hazard prevention</li> <li>• To realize the complete program for realization of safe products within the organization</li> <li>• Identify different types of errors in the man - machine system and to apply appropriate solutions aimed at eliminating errors</li> <li>• Conduct an ergonomic evaluation of design solutions of manuals</li> <li>• Design technical and project documentation in accordance with the ergonomic recommendations</li> </ul> |
| 3.5 | industrial engineering | 1458 | elective | <b>Improving the quality of business processes - Lean 6 Sigma</b> | <p>The aim of the course is to acquaint students with modern approaches and methods for improving the quality of production processes, using Lean management approaches and the Six Sigma methodology, and students to be able to apply the aforementioned tools.</p>                                                                                                                                                                                                  | <p>Upon completion of the course, students are able to: 1. Understand the concept of Lean - resource-saving production. 2. Understand Lean tools and capacity utilization, including Kaizen and Gemba procedures. 3. They understand and apply quality control methods in production, including the Six Sigma methodology. 4. They understand the basics of integrating the Lean concept and the Six Sigma methodology. 5. They master the methodology of experiment design, which includes the method of setting up, conducting the experiment and realizing the analysis and post-analysis of the modern approach of statistical design of experiments,</p>                                                                                                                                                                                                                                                                     |

|     |                                                  |      |            |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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|     |                                                  |      |            |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | including the interpretation of regression and correlation analysis.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 3.5 | process and environmental protection engineering | 1063 | elective   | <b>Drying and dryers</b>                               | Students will be introduced to technical bases of materials drying process. The goal of this course is a review of the dryers basic constructions. Through this course students acquire skills and knowledge to recognize problems that occur in complex drying processes.                                                                                                                                                                                            | Successful completion of the study program student acquires specific skills in function of quality performance of professional activities. It is anticipated that students acquire knowledge on specific technical solutions in the fields of drying materials, as well as being able to analyze complex technical solutions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 3.5 | agricultural engineering                         | 1456 | elective   | <b>Plant design for food production and processing</b> | 1. Master the theoretical foundations of the design of machinery, equipment and technological lines for manufacturing and food processing; 2 Getting to know your limitations and the specific production lines and food processing; 3 Introduction to the principles of the design of machinery and equipment manufacturing and food processing; 4 Acquire practical skills in analyzing the set of engineering problems and its solving multidisciplinary approach. | After successful completion of this course, studenty should be able to: <ul style="list-style-type: none"> <li>• Define the project management plan,</li> <li>• Describe the production technology and food processing,</li> <li>• Select the appropriate machinery and equipment for the design of complete lines and factories for processing agricultural products,</li> <li>• Design complete line and / or factory for the production, processing and storage of agricultural products,</li> <li>• Estimates of the outcomes of the project in relation to the initial request,</li> <li>• Estimates energy required for food processing,</li> <li>• Be efficient in teamwork,</li> <li>• Estimates of economic analysis,</li> <li>• Preparing and exposing projects to potential investors.</li> </ul> |
| 4.1 | theory of machanisms and machines                | 1514 | obligatory | <b>Skill Praxis M - IGM</b>                            | 1. Acquisition of practical knowledge in the field of engineering graphics, computer simulations, mechatronics and virtual reality.<br>2. Acquaintance with software tools                                                                                                                                                                                                                                                                                            | After completing the study program the study program, the student acquires the ability to solve practical problems in the area of: <ul style="list-style-type: none"> <li>- engineering graphics</li> <li>- computer simulations</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

|     |   |      |            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
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|     |   |      |            | required for application in the field of engineering graphics, computer simulations, mechatronics and virtual reality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | - mechatronics<br>- virtual reality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|     |   |      |            | 3. Developing the student's creative abilities for solving concrete problems in the mentioned areas.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b><br><br>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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. | Upon the successful completion of M.Sc. Thesis Project, engineers should be able to: <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> </ul> |

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|     |   |      |            |                     | <ul style="list-style-type: none"> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Hydropower Engineering

| position | department             | ID   |            | title                           | goal                                                                                                                                                                                                                                                                                                                                                   | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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| 1.1      | hydropower engineering | 1000 | obligatory | <b>Theory of Turbomachinery</b> | 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. | On successful completion of this course, students should be able to:<br>1. Identify and describe the different types and designs of turbomachinery (hydraulic turbines, pumps, fans and turbocompressors),<br>2. Explain the flow process and exchange of energy in turbomachinery,<br>3. Identify and analyze energy and exploitation characteristics of turbomachinery,<br>4. Explain the cavitation phenomenon in pumps and hydraulic turbines.                                                                                                            |
| 1.2      | hydropower engineering | 1422 | obligatory | <b>Pumps</b>                    | Acquiring the knowledge of engineering application of pumps as machines for raising the energy to fluid. Ability to work in practice on various types of installations, as well as to design installations that contain a pump as a built-in element with its function.                                                                                | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps, 2. calculate the energy parameters of the pump, 3. calculate and apply dimensionless parameters (coefficients) of the pump, 4. determine the duty point of the system, 5. apply the energy characteristics of the pump when coupling and regulating the pump, 6. apply the most energy efficient way of regulation of the pumps, 7. choose the adequate pump, 7. calculate the cavitation reserve of the pump and plant. |
| 1.3      | mechanics              | 0004 | elective   | <b>Mechanics M</b>              | 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                                                                                                              | Upon successful completion of this course, students should be able to:<br>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.<br>• Analyze the motion of variable mass particle.                                                                                                                                                                                                                                                                                                 |

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|     |                 |      |          |                          | 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.                                                                                                                           | <ul style="list-style-type: none"> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul>                                                                                                                       |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | 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. | 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. |
| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b>  | 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                                                                               | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real</li> </ul>                                                                                                                                                                                                                                                                                                                                                    |

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.

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.

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>                     | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements. | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution. |
| 1.5 | fluid mechanics                   | 1558 | elective | <b>Transport of fluid through pipes</b> | The goal of studying the subject is to learn and study important engineering problems related to the pipeline transport of fluids, and especially to the calculation methods of water pipelines, oil pipelines,                                                                                                                                     | As a result of studying the subject, mastering theoretical assumptions, physical laws, approximations and calculation methods of one-dimensional fluid flows through special purpose pipelines, such as: water pipelines, hot water                                                                                                                  |

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|     |                                    |      |          |                                                 | gas pipelines and steam pipelines. The goal is also to get acquainted with the problems of: water hammer, corrosion of pipelines, methods of pipe support and techno-economic analysis of pipeline transport.                                                                                                                                                       | pipelines, oil pipelines, gas pipelines and steam pipelines. As a result of the course, practical knowledge is obtained to solve technical problems: water hammer in pipelines, corrosion of pipelines, thermal expansion of pipelines and ways of supporting pipes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b>                       | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines. | Upon successful completion of this course, students should be able to:<br>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;<br>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;<br>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;<br>4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.<br>Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.<br>Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved. |
| 1.5 | internal combustion engines        | 1435 | elective | <b>Internal Combustion Engines Fundamentals</b> | The course provides a comprehensive insight into the matter of teh internal combustion (IC) engines (theoretical cycles, actual process, engine systems,                                                                                                                                                                                                            | Adopted theoretical and practical knowledge in the field of engines. Connecting fundamental disciplines: thermodynamics, fluid mechanics, mechanics, material resistance, etc. on a complex                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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|     |                             |      |            |                                | operating characteristics). It is intended for students at the Department for IC engines, as an introduction to a deeper study of specific areas of internal combustion engines, as well as students of those fields where knowledge of IC engines as a propulsion unit (motor vehicles, shipbuilding, railway engineering, mechanization) is necessary.                                                                                              | object such as the internal combustion engine. Acquiring the skills for a competent approach in the selection, organization of operation and maintenance of engines. Acquiring a base for further study of specific problems, construction and design of engines.                                                                                                                                                                                                                                                                                                                                                           |
| 1.5 | thermal science engineering | 1256 | elective   | <b>Central Heating Systems</b> | 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.                                                                                                                   | 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.                                                                                                                                                                                                                                                                                                                    |
| 2.1 | hydropower engineering      | 0808 | obligatory | <b>Hydraulic turbines</b>      | Achieving academic competence in the fields of hydraulic turbines and hydropower.<br>Mastering theoretical knowledge of flow process through the turbines and energy transformation therein (fluid and mechanical system interaction).<br>Obtaining practical knowledge in optimal energy and cavitation performances calculation of hydraulic turbines.<br>Having the relevant know-how for the turbine industry, design companies and power plants. | On successful completion of this course the students will be able to:<br>- recognize different types and constructions of hydraulic turbines,<br>- describe the principles of operation, explain and analyze fluid flow in various hydraulic turbines,<br>- define, calculate and analyze the specific geometry, energy and cavitation parameters of hydraulic turbines,<br>- construct the essential components and explain their roles from the point of the optimal energy transfer process in various hydraulic turbines,<br>- 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).

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| 2.2 | hydropower engineering | 1424 | obligatory | <b>Design of Pumps, fans and turbo compresors</b> | The knowledge of engineering design of pumps, fans and turbo compresors. Ability to work in design and development offices in the pump, fan and turbo compresor industry. Ability to innovate project methods.                                                                              | Upon successful completion of this course, students will be able to:<br>1. design pumps, fans and turbocompressors according to various procedures,<br>2. analyze the consequences of different design approaches,<br>3. use and analyze hydraulic, numerical and experiential data used in design,<br>4. model the geometry of pumps, fans, turbo compresors.                                                                                                                                                                                                                                                                                                |
| 2.3 | hydropower engineering | 0809 | obligatory | <b>Fans and turbocompressor s</b>                 | 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. | Upon successful completion of this course, students should be able to:<br>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,<br>2. determine the duty points of the ventilation system and fan,<br>3. select the appropriate fan and the most energy efficient way of its regulation,<br>4. determine the duty point of the fan by using the dimensionless parameters (characteristic coefficients),<br>5. calculate the fan characteristics when working with other fluid density,<br>6. calculate the thermodynamic and energy |

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|     |                        |      |          |                                                        | parameters of the turbocompressor,<br>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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 2.4 | aerospace engineering  | 1130 | elective | <b>Wind Turbines 2</b>                                 | <p>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.</p> <p>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).</p> |
| 2.4 | hydropower engineering | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | <p>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</p> <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,</li> <li>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,</li> <li>3. Process and present the measurement results,</li> <li>4. Calculate the measurement uncertainty,</li> <li>5. Explain the calibration of velocity, pressure and</li> </ol>                                                                                                                                                                                 |

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|     |                                    |      |          |                                        | their transformation into electrical quantities using sensors. Through specific measurements in the laboratory, students are introduced to the field of practical experimental methods.                                                                                                                                                                                                                            | flow measuring devices,<br>6. Describe the types and characteristics of sensors.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>                     | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design. | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                                                                                                                                                                                                                                                                                                    |
| 2.4 | mechanics                          | 0037 | elective | <b>Theory of Mechanical Vibrations</b> | 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.                                                                                                                                                                                               | Upon successful completion of this course, students will be able to: <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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).</li> <li>•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</li> </ul> |

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.

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| 2.5 | control engineering | 0599 | elective | <b>Industrial Automation</b> | 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. | <p>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.</p> <p>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.</p> <p>Student is able to create HMI project with operators panel.</p> |
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| 2.5 | thermal power engineering                        | 1499 | elective | <b>Thermal Turbomachinery</b>                                | <p>1. The achievement of academic competence in the field of steam and gas turbines and thermal power engineering.</p> <p>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).</p> <p>3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam and gas turbines.</p> <p>4. The achievement of the techniques of process modeling.</p> <p>5. Mastering the methods of experimental work in thermal power engineering.</p> | <p>1. Academic deep knowledge of the thermodynamic cycle and flows in steam and gas turbines and turbine plants</p> <p>2. The development of critical thinking about energy use, fuel efficiency and environmental preservation</p> <p>3. The ability of calculate heat balance diagrams and main parameters of the steam and gas turbine power plants.</p> <p>4. Ability to use computer technology for modeling and calculations</p> |
| 2.5 | process and environmental protection engineering | 1124 | elective | <b>Principles of environmental and work space protection</b> | The main course objectives are related to introduce students to environmental problems, natural hazards and human impact on the environment. In order to solve problems, students will be acquainted with the physics and chemistry of the environment, atmospheric phenomena, the basics of microbiology and ecology.                                                                                                                                                                                                                                                                        | Based on lessons envisaged to overcome the students will be able to make independent decisions related to environmental management, sustainable development, impact assessment of projects and facilities on the environment. Especially important is the knowledge that students acquire in terms of life cycle analysis of products and processes.                                                                                   |
| 2.5 | process and environmental protection engineering | 1059 | elective | <b>Energy in process engineering</b>                         | Mastering the basic knowledge and skills of using the energy in process industry in order to adequately deal with the practical matters of rational use of energy and maintenance of energy equipment and systems in industrial companies. In                                                                                                                                                                                                                                                                                                                                                 | Understanding the operation of energy equipment and technologies and principles of their rational use. Preparation of the energy balance of industrial companies; implementation of energy auditing procedure, energy data collection and implementation of methodology for defining the                                                                                                                                               |

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|     |                        |      |            |                                         | addition, basic knowledge of the transformation and energy use are essential for the understanding of matter from other subjects of process engineering and environmental protection.                                                                                                                                                                                                            | energy losses of equipment and installations in industrial plants. Understanding basic terms within Energy Management System (ISO 50001:2011). Basic concept of BAT (Best Available Techniques) in energy efficiency in industrial plants.                                                                                                                                                                                                                                                                                   |
| 2.5 | hydropower engineering | 1425 | elective   | <b>CFD Modelling of Turbo-machinery</b> | The knowledge of engineering numerical design of turbomachines. Ability to work in design and development offices in the turbomachinery industry. Ability to innovate design methods, as well as to acquire the basis for academic development in terms of the application of computational fluid mechanics.                                                                                     | Upon successful completion of this course, students will be able to:<br>1. apply different procedures for designing turbomachines,<br>2. compare geometric and energy characteristics of turbomachines obtained by applying different calculation approaches,<br>3. perform engineering calculations, using modern software for geometry construction (CAD) and flow calculation (CFD) in turbomachines,<br>4. have the skill to work in a computer environment,<br>5. analyze and present the obtained calculation results. |
| 3.1 | hydropower engineering | 0810 | obligatory | <b>Hydropower plants and equipment</b>  | Achieving academic competence in the field of hydropower plants, equipment and hydro energy.<br>Obtaining practical knowledge in hydropower plants designing and the content of the technical project documentation.<br>Mastering knowledge of how to choose and calculate hydromechanical equipment installed in hydroelectric and pump stations.<br>Developing the ability to find the optimal | On successful completion of this course the students will be able to:<br>- define, plan and organize the phases of project design, build up and operation of hydropower plants within electro energy and water supply systems,<br>- design the optimal hydro mechanical equipment (trash racks, valves, pipes etc.),<br>- 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,                     |

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|     |                        |      |            |                                     | <p>solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.</p> <p>Improving individual creative abilities in performing professional design of hydro energy systems.</p>                                                                                                                      | <ul style="list-style-type: none"> <li>- analyze the transient operating regimes and unsteady fluid flow (water hammer) in various energy systems,</li> <li>- collect, analyze and present the calculation results,</li> <li>- choose the optimal solution to the specific case by analyzing more possible solutions from the point of energy and economy,</li> <li>- work as a part of a team as well as demonstrate their entrepreneurial skills.</li> </ul>                                                            |
| 3.2 | hydropower engineering | 1376 | obligatory | <b>Hydraulic power transmitters</b> | <p>Theory and practical skills about hydraulic power transmission, with focus on hydrodynamic power transmission. Selection and application of hydraulic transmission.</p>                                                                                                                                                                                | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. identify and describe the various types and constructions of the hydraulic power transmission systems (hydraulic torque converter, hydraulic coupling and brake), and the principles of their work,</li> <li>2. select the appropriate hydraulic power transmission system,</li> <li>3. examine the hydraulic power transmission system according to the valid international standard.</li> </ol> |
| 3.3 | hydropower engineering | 0927 | obligatory | <b>Hydropower measurements</b>      | <p>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</p> | <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Organize and carry out testing of hydraulic machines (turbines, pumps, fans and turbocompressors) in the laboratory, following applicable international standards,</li> <li>2. Process, present and analyze test results and calculate measurement uncertainty of the measured values,</li> </ol>                                                                                                   |

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|     |                        |      |          |                        | subject, the characteristics of valves and methods for determining the cavitation characteristics of hydraulic machines and equipment are studied in detail.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <p>3. Perform a comparative analysis of number of ways for measuring the energy parameters of hydraulic machines,</p> <p>4. Recalculated efficiency from a model to a prototype of turbine,</p> <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                              |
| 3.4 | production engineering | 0920 | elective | <b>Machine tools M</b> | <p>1. To develop ability to perceive typical missions of machining systems.</p> <p>2. To study machine tools mechanisms and systems for their control and programming.</p> <p>3. To receive training in testing procedures for machine tools.</p> <p>4. To develop ability to analyze complex machine tools and machining systems equipment.</p> <p>5. The develop ability to analyze the resources for machine tools development.</p> <p>6. To study configuring and/or building of machine tools for planned mission.</p> <p>7. To receive training for realization of one mission of machine tools through writing the seminar work.</p> <p>8. To know how to make technical projects.</p> | <p>Upon successful completion of this course students should be able to:</p> <p>1. Recognize typical missions of manufacturing systems.</p> <p>2. Apply basic types of machine tool mechanisms in their design.</p> <p>3. Configure the control of CNC machine tools based on systems with open architecture.</p> <p>4. Program new generation machine tools using different programming methods.</p> <p>5. Evaluate the quality of machine tools and machining system based on applied standard test procedures.</p> <p>6. Configure mechine tool for their own needs.</p> <p>7. Apply the acquired knowledge on the available resource for the development and / or improvement of machine tools and manufacturing systems.</p> <p>8. Prepare Technical Elaborate and reports about testing and programming of machine tools.</p> |

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| 3.4 | thermal science engineering | 1254 | elective | <b>Building energy certification</b>      | 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. | 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.                                                                                                                                                                                                                                                                                                                                                                                   |
| 3.4 | fluid mechanics             | 1559 | elective | <b>Computational Fluid Dynamics (CFD)</b> | 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.                                                                                                                                                                                                                                                                                                                                                            | <p>Upon successful completion of the course, students will be able to:</p> <ul style="list-style-type: none"> <li>- explain the general principles of numerical solution of governing equations for fluid flow</li> <li>- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow</li> <li>- explain and apply principles of numerical grid generation</li> <li>- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)</li> <li>- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar</li> </ul> |

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|     |                        |      |          |                                                             | incompressible flow in various domains                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <ul style="list-style-type: none"> <li>- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 3.4 | hydropower engineering | 0928 | elective | <b>Renewable energy resources - small hydropower plants</b> | <p>Achieving academic competence in the field of small hydropower plants, hydromechanical equipment and hydro energy.</p> <p>Obtaining practical knowledge in small hydropower plants designing and the content of the technical project documentation.</p> <p>Mastering knowledge of how to choose and calculate hydromechanical equipment installed in small hydroelectric stations.</p> <p>Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.</p> <p>Improving individual creative abilities in performing professional design of small</p> | <p>On successful completion of this course the students will be able to:</p> <ul style="list-style-type: none"> <li>- define, plan and organize the phases of project design, build up and operation of small hydropower plants,</li> <li>- 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,</li> <li>- check the adopted geometry and operating characteristics by basic analysis of the transient operating regimes and water hammer phenomenon,</li> <li>- collect, analyze and present the calculation results,</li> <li>- choose the best solution to the specific case by analyzing more possible solutions from the point of energy efficiency,</li> <li>- work as a part of a team as well as demonstrate their entrepreneurial skills.</li> </ul> |
| 3.5 | fluid mechanics        | 0940 | elective | <b>Microfluidics and Nanofluidics</b>                       | <p>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</p>                                                                                                                                                                                                                                                                                                                                                                                                        | <p>Students are trained to:</p> <ul style="list-style-type: none"> <li>-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;</li> <li>-determine the velocity and pressure field for</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

and nanometer characteristic dimensions.

- 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.

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| 3.5 | control engineering | 0656 | elective | <b>Intelligent Buildings</b> | To introduce students to the concept of intelligent buildings, technical systems in modern buildings and control systems technology and their integration. | <p>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.</p> <p>Student is able to create ETS project and program KNX components.</p> <p>Student is able to make application schematics of HVAC system, to define signal list and define quote of sensors, actuators and controllers.</p> |
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| 3.5 | thermal power engineering | 1320 | elective   | <b>Computer simulations of thermalhydraulic processes and CFD</b> | 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. | 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.                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 3.5 | thermomechanics           | 0924 | elective   | <b>Solar energy</b>                                               | Achieving academic competences in the field of solar energy utilization. Acquiring theoretical and practical knowledge on converting solar into thermal energy, acquiring skill of modeling and simulation of processes.                                                                                                                                                                            | <p>Upon successful completion of this course students should be able to:</p> <ul style="list-style-type: none"> <li>• Explain the characteristics of solar radiation at a specific location;</li> <li>• Analyze energy transport in the elements of the solar thermal systems;</li> <li>• Formulate the mass and energy balances for the elements of the solar system (for solar collectors, thermal energy storages, heat exchangers, pipelines);</li> <li>• Determine representative energetic characteristics of appropriate elements of the system;</li> <li>• Analyze and thermodynamically evaluate the operation of various solar thermal systems.</li> </ul> |
| 4.1 | hydropower engineering    | 1210 | obligatory | <b>Skill Praxis M - HEN</b>                                       | 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                                                                                                                                                                                            | <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Write a report with a completed skill praxis,</li> <li>2. Describe the operation and organization of the appropriate energy system or facility,</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                     |

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|     |   |      |            | 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. | <p>3. Demonstrate acquired practical experience and skills, related to specific jobs in the appropriate energy systems or facilities,</p> <p>4. Acquire and develop team skills in work environment (communication with colleagues, professional ethics, etc.).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                                                                                                                                                                                                                                                                                                                                  | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> </ul> |

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|     |   |      |            |                     | <ul style="list-style-type: none"> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Industrial Engineering

| position | department             | ID   |            | title                         | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
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| 1.1      | industrial engineering | 0421 | obligatory | <b>Operations Research</b>    | 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.                                                                                                                                                                                                                  | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 1.2      | industrial engineering | 1457 | obligatory | <b>Engineering statistics</b> | The objectives of the course are to familiarize students with the basics of statistical methods used in industrial practice. The first step involves analyzing the characteristics of the data. The focus of the course is on identifying the problem, choosing the appropriate method through defined procedures and drawing conclusions, both mathematical and engineering. On the basis of engineering conclusions, the results are interpreted and appropriate engineering decisions are made. | After passing the exam, students are expected to know how to use: 1. statistical methods for objective problem solving in practice, 2. to draw the necessary conclusions using parametric and non-parametric research that includes hypothesis testing, one-way and two-way analysis of variance, simple and multiple regression and correlation, the 3rd goal of learning and practicing is correct problem setting, 4. determining the methodology of problem solving based on the results of descriptive statistics 5. implementing the appropriate statistical procedure defined by the steps of the procedure 6. correct engineering interpretation of the obtained results, with knowledge of their mathematical interpretation and 7. Getting to know the programming language R. |
| 1.3      | fluid mechanics        | 1290 | elective   | <b>Fluid Mechanics M</b>      | Main goal is to learn student general principles of fluid mechanics and how to apply them in solving practical engineering problems. In that sense                                                                                                                                                                                                                                                                                                                                                 | 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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|     |                                   |      |          |                     | proper understanding of general laws and equations is necessary. This will also enable student to develop further in other topics based on fluid mechanics.                                                                                                                                                                                                                                                                    | (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.                                                                                                                                                                                                                                                                                                                                                     |
| 1.3 | mechanics                         | 0004 | elective | <b>Mechanics M</b>  | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b> | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control                                                                                                                                                                                                                                                                       | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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|     |                 |      |          |                                   | module, and the work algorithm.<br>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.                                                                                                                                                                                                                                                                                                                                       | mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b>           | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |
| 1.5 | mathematics     | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important                                                                                                                                                                                                                                                                                                                                                                                                              | Upon successful completion of this course, students should be able to:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

application in technics. Introduction to techniques of regression analysis and stochastic modelling.

- 1) Calculate probability and conditional probability of random events.
- 2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.
- 3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.
- 4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.
- 5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.
- 6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | information technologies | 1303 | elective | <b>Computer Networks</b> | <p>Course objective:</p> <ul style="list-style-type: none"> <li>• Introduction to the concept, standard tasks and operation of computer networks.</li> <li>• 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.</li> </ul> | <p>The acquired knowledge allows students:</p> <ul style="list-style-type: none"> <li>• to identify and suggest the type of computer network,</li> <li>• to understand the problems that arise whendesigning computer networks,</li> <li>• to create a project of computer network that includes a sugestion purchase of necessary equipment.</li> </ul> |
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| 1.5 | industrial engineering | 0523 | elective   | <b>Management Information Systems</b> | 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.                                            | Upon successful completion of this course, students should be able to:<br>- Use software tools for decision support,<br>- Design models for decision-making process in DSS tools,<br>- Using expert systems in the field of industrial engineering,<br>- Projected base of knowledge in expert systems,<br>- Estimates of efficiency designed models in the specific case study.                                                                                              |
| 2.1 | industrial engineering | 1369 | obligatory | <b>Industrial logistic</b>            | 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.                                                          | 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.                                                                                                                                                                                                  |
| 2.2 | industrial engineering | 0417 | obligatory | <b>Ergonomic designing</b>            | 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. | Upon successful completion of this course, students should be able to:<br>• Apply ergonomic approach to all stages of the design process, during the design of simple or complex systems<br>• To apply various ergonomic tools for the purpose of realization of a project<br>• 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

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| 2.3 | industrial engineering | 0521 | obligatory | <b>Database Systems</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- use SQL language,</li> <li>- 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.).</li> <li>- Analyze the results obtained by the queries established for business analysis,</li> <li>- Estimates of efficacy of queries a established for</li> </ul> |
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the different methods of industrial engineering.

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| 2.4 | hydropower engineering      | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | 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. | On successful completion of this course, students should be able to:<br>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,<br>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,<br>3. Process and present the measurement results,<br>4. Calculate the measurement uncertainty,<br>5. Explain the calibration of velocity, pressure and flow measuring devices,<br>6. Describe the types and characteristics of sensors. |
| 2.4 | internal combustion engines | 1478 | elective | <b>Sensors and Computer Based Measurements</b>         | 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 to the world of virtual instrumentation and graphical programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in functioning and using DAQ systems through numerous, real-world examples. To get closer acquaintance with the                                                                                                               | 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 applications (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 the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.   |

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|     |                        |      |          |                                                        | sensors, and digital acquisition software & hardware, in general, and methods of DACQ software development and testing.                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 2.4 | industrial engineering | 0513 | elective | <b>Risk management in Terotechnology</b>               | The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to apply production and maintenance systems based on risk management, due to knowledge in the identification, analysis, risk assessment and decision-making on the basis of those facts.                                                                                                                                                         | 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. |
| 2.5 | production engineering | 0722 | elective | <b>Computer Simulation in Manufacturing Automation</b> | 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 | After successfully completing this course, the students should be capable to: <ul style="list-style-type: none"> <li>- Create and implement stochastic simulation;</li> <li>- Create conceptual model for discrete event simulation;</li> <li>- Create and implement discrete event simulation within fixed and flexible automation framework;</li> <li>- Create conceptual and computer model for continuous simulation of various processes;</li> <li>- Integrate continuous and discrete event simulation;</li> <li>- Manage discrete event simulation project.</li> </ul>                                                                                                                                                                                                               |

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|     |                        |      |            |                                                 | of computer simulation application in automation; to get familiar with the role of computer simulation within digital factory.                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 2.5 | control engineering    | 0599 | elective   | <b>Industrial Automation</b>                    | 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.                                                                                                                   | 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.<br>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.<br>Student is able to create HMI project with operators panel. |
| 2.5 | industrial engineering | 1370 | elective   | <b>Design of logistic and warehouse systems</b> | 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. | 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.                                                                                                                                                                                                                                                                                                                |
| 3.1 | industrial engineering | 0413 | obligatory | <b>Production and Operations Management 2</b>   | Studying the management process of business-production system in its interaction with the environment. Identification of problems in                                                                                                                                                                                                                                    | Upon the successful completion of this course, students should be able to:<br>- discuss the problems of business-production planning, organization and management,                                                                                                                                                                                                                                                                                                                                                                                                                          |

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.

- 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.

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| 3.2 | industrial engineering | 0574 | obligatory | <b>Organization Design</b> | <p>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 organizationally shaped organizational system (enterprise or its parts) achieves the pursued objectives and goals.</p> | <p>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:</p> <ul style="list-style-type: none"> <li>-tackle an organisation design project</li> <li>-sequence and approach the design effectively</li> <li>-apply various tools and techniques to make good organisation</li> <li>-design decisions</li> <li>-control the consequences and risks of design changes</li> <li>-recognize design project blockers and challenges and</li> <li>-address design project blockers and challenges.</li> </ul> |
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| 3.3 | industrial engineering | 1417 | obligatory | <b>Industrial Management</b>                                | <p>The aim of this course is to acquaint students with the basic principles, methods and techniques of management in general, and especially in industrial enterprises. The goal is to acquire knowledge and skills that will be a solid basis for further acquisition of competencies for independent and responsible participation in business decision-making processes in modern conditions.</p>                                                                                                                                                                                                                                                       | <p>Mastering the material from the subject Industrial Management provides modern knowledge of the theory and practice of business management in general, and especially in industrial enterprises, with an emphasis on achieving competence to strengthen innovation as a key factor in competitiveness in turbulent business environment, domestic and foreign.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 3.4 | hydropower engineering | 0928 | elective   | <b>Renewable energy resources - small hydropower plants</b> | <p>Achieving academic competence in the field of small hydropower plants, hydromechanical equipment and hydro energy.</p> <p>Obtaining practical knowledge in small hydropower plants designing and the content of the technical project documentation.</p> <p>Mastering knowledge of how to choose and calculate hydromechanical equipment installed in small hydroelectric stations.</p> <p>Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.</p> <p>Improving individual creative abilities in performing professional design of small</p> | <p>On successful completion of this course the students will be able to:</p> <ul style="list-style-type: none"> <li>- define, plan and organize the phases of project design, build up and operation of small hydropower plants,</li> <li>- 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,</li> <li>- check the adopted geometry and operating characteristics by basic analysis of the transient operating regimes and water hammer phenomenon,</li> <li>- collect, analyze and present the calculation results,</li> <li>- choose the best solution to the specific case by analyzing more possible solutions from the point of energy efficiency,</li> <li>- work as a part of a team as well as demonstrate their entrepreneurial skills.</li> </ul> |
| 3.4 | industrial             | 1248 | elective   | <b>Techno-</b>                                              | Students acquaintance with the goals of                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Upon completion of the course syllabus students                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|     | engineering                                      |      |          | <b>economic analysis and project management</b> | 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. | <p>will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul> |
| 3.4 | process and environmental protection engineering | 1061 | elective | <b>Economic analysis in process engineering</b> | Familiarize students with the basic concepts of economic analysis, through the study of the capital and operating costs, shortcut methods of economic optimization and economic analysis of investment.                   | <p>Students will be able to:</p> <ul style="list-style-type: none"> <li>* calculate the investment costs</li> <li>* calculate the operating costs</li> <li>* determine the economic parameters of investment profitability</li> <li>* use the shortcut procedures for determining of the optimal pipeline diameter and optimal insulation thickness</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

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| 3.4 | process and environmental protection engineering | 1062 | elective | <b>Maintenance in process industry</b> | <p>The objective of the course is that students acquire theoretical and practical knowledge in the field of maintenance of technical systems (concept, technology...). Through teaching activities, students acquire creative and specific practical skills that qualify them to work in the field of maintenance of equipment, machines and systems in process industry.</p>                                                                                          | <p>By successful completion of the study program student acquires the following skills: analysis, synthesis and prediction of solutions and consequences in the field of maintenance in process industry; development of critical thinking and self-critical approach; application of knowledge in practice; professional ethics; correlation of knowledge from different fields and their applications; involvement in the activities related to maintenance in the company.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 3.5 | industrial engineering                           | 0520 | elective | <b>Man - machine system design</b>     | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Identify the main types of mechanical hazards</li> <li>• Carry out the selection and to apply the basic types of safety protections on machines</li> <li>• Perform the identification of all other types of hazards in the working environment and to implement hazard analysis in a man - machine system</li> <li>• Apply basic procedures for hazard prevention</li> <li>• To realize the complete program for realization of safe products within the organization</li> <li>• Identify different types of errors in the man - machine system and to apply appropriate solutions aimed at eliminating errors</li> <li>• Conduct an ergonomic evaluation of design solutions of manuals</li> <li>• Design technical and project documentation in accordance with the ergonomic recommendations</li> </ul> |
| 3.5 | production engineering                           | 1537 | elective | <b>Computer control and</b>            | <p>The goal of the course is for students to acquire the necessary knowledge in the</p>                                                                                                                                                                                                                                                                                                                                                                                | <p>After completing this course the students should be able to: 1. Apply a stepper motor to actuate a</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

**monitoring in  
manufacturing  
automation**

application, design, and implementation of modern computer control and monitoring systems in manufacturing automation, as well as to get skills for solving practical problems of computer control and monitoring in automation.

mechanical system within the manufacturing process, including designing the hardware architecture and control system based on integrated microcontrollers; 2. Implement a system for moving two or more controlled axes using interpolation algorithms based on the direct search method; 3. Physically realize the task of multi-axis movement defined in G-code on a microcontroller platform with interpolation algorithms based on direct search methods; 4. Generate a program for the movement of anthropomorphic robots and achieve their integration with the sensor environment by including real-time signal processing; 5. Conceptualize a system for computer monitoring of the manufacturing process.

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| 3.5 | fluid mechanics | 0940 | elective | <b>Microfluidics and Nanofluidics</b> | <p>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.</p> | <p>Students are trained to:</p> <ul style="list-style-type: none"><li>-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;</li><li>-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;</li><li>- calculate the velocity and pressure field for isothermal compressible gas flow in micro channels, pipes and bearings for the slip flow regime;</li><li>- calculate the velocity, pressure and temperature field for non-isothermal compressible gas flow in micro channels, for the slip flow regime;</li><li>-calculate the pressure and velocity field for electroosmotic flow in micro and nano channels</li></ul> |
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|     |                        |      |            |                                                                   |                                                                                                                                                                                                                                                                       | <p>and pipes;</p> <ul style="list-style-type: none"> <li>- apply 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;</li> <li>-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.</li> </ul>                                                                                                                                                                                                                                                 |
| 3.5 | industrial engineering | 1458 | elective   | <b>Improving the quality of business processes - Lean 6 Sigma</b> | <p>The aim of the course is to acquaint students with modern approaches and methods for improving the quality of production processes, using Lean management approaches and the Six Sigma methodology, and students to be able to apply the aforementioned tools.</p> | <p>Upon completion of the course, students are able to: 1. Understand the concept of Lean - resource-saving production. 2. Understand Lean tools and capacity utilization, including Kaizen and Gemba procedures. 3. They understand and apply quality control methods in production, including the Six Sigma methodology. 4. They understand the basics of integrating the Lean concept and the Six Sigma methodology. 5. They master the methodology of experiment design, which includes the method of setting up, conducting the experiment and realizing the analysis and post-analysis of the modern approach of statistical design of experiments, including the interpretation of regression and correlation analysis.</p> |
| 4.1 | industrial engineering | 1250 | obligatory | <b>Skill Praxis M - IIE</b>                                       | <p>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</p>                                   | <p>This course attendance enables the following:</p> <ul style="list-style-type: none"> <li>- 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.</li> <li>- Student connects the knowledge acquired in other</li> </ul>                                                                                                                                                                                                                                                                                                                                           |

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|     |   |      |            | 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. | <p>courses.</p> <ul style="list-style-type: none"> <li>- Student identifies and critically examines models of organization and flow of business information.</li> <li>- 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.</li> <li>- Student establishes the personal contacts and friendships that will be able to use during the study or when entering into future employment.</li> </ul> <p>Upon completion of the course, students have practical knowledge and skills in the field of business organization and sustainable development of enterprises.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                                                                                                                                                    | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct,</li> </ul> |

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|     |   |      |            |                     | <p>analyse and interpret the results;</p> <ul style="list-style-type: none"> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                 |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Internal Combustion Engines

| position | department                  | ID   |            | title                                                 | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| 1.1      | internal combustion engines | 0852 | obligatory | <b>Engine Working Processes</b>                       | 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.                                                                                                                                                                                                                                                                                                                         | Merging a theoretical knowledge of thermodynamics and fluid mechanics, connecting and application on real object – internal combustion engine.<br>Training for basic modeling and calculating of real engine working process, as well as acquiring fundamentals of engine designing.<br>Mastering of engine working parameters and operating characteristics and of the influences of working process on operating, energetic and ecologic engine characteristics. |
| 1.2      | internal combustion engines | 1086 | obligatory | <b>Mixture formation and combustion in IC engines</b> | The aims of the course are to provide a comprehensive insight into the subject matter of Engine Fueling and Mixture formation in IC Engines. Broadening existing and acquiring new knowledge in hydrodynamics by studying spray and droplet formation and break-up. Broadening knowledge on geometric and process parameters influencing the quality of air-fuel mixture. Understanding the influence of air-fuel mixture time-space characteristics on engine combustion process dynamics and performance. Acquiring skills in calculating and simulating characteristics of fuel spray and droplet in time, angle and space domain. | Students are capable of performing calculation of spray formation and break-up, primary and secondary fuel droplet break-up for given injection system parameters in terms of high pressure pump, fuel line and injector. Students are capable to determine fuel droplet SMD (Sauter Mean Diameter) and time required for droplet evaporation for thermodynamic parameters during engine cycle.                                                                    |

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| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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.</p>                                                                                                                                                     |

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.</p> <p>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p>                                                                                                                                                                          | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |

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| 1.5 | mathematics            | 0354 | elective | <b>Probability and statistics</b>             | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                        | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> <li>2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.</li> <li>3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.</li> <li>4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.</li> <li>5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.</li> <li>6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.</li> </ol> |
| 1.5 | general machine design | 1483 | elective | <b>Practicum in engineering design basics</b> | Introduction to the engineering design basics for typical machine parts, elements and assemblies. Application of basic previously acquired knowledge and skills for the design of machine parts, elements and assemblies (computer graphics, material technology, machine elements | <p>At the end of this course, the student should be able to:</p> <ul style="list-style-type: none"> <li>- recognise and explain the construction of machine parts, elements and assemblies (from the aspect of material technology, manufacturing and assembly technology, and application);</li> <li>- to apply basic knowledge about the dominant</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

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|     |                                    |      |          |                               | calculations, production technology).<br>Preparation of technical documentation.<br>Generating fundamentals for higher levels of complex machine systems design and product development.                                                                                                                                                                                                                                                                                       | influences on construction (static strength, dynamic durability, stiffness, load-bearing capacity, service life, reliability, technological aspects, economic aspects, user needs, market requirements) in the design of machine parts, elements and assemblies;<br>- to create construction documentation and instructions for installation, use and maintenance.                                                                                                                                                                                                                                                                                                   |
| 1.5 | thermomechanics                    | 1375 | elective | <b>Heat and Mass Transfer</b> | Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering. Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer. | Upon successful completion of the course, students should be able to:<br>• Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.<br>• Explain the heat transfer in semi-infinite bodies.<br>• Perform the heat transfer calculation in semi-infinite bodies.<br>• Apply numerical methods for solving the problems of unsteady heat conduction.<br>• Apply the basic laws of radiation in the in the calculation of radiation of the gas mixture.<br>• Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer. |
| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b>     | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines.                                                                                                            | Upon successful completion of this course, students should be able to:<br>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;<br>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;<br>3) recognize the need for the application of appropriate electrical machine to the requirements                                                                                                                                                                                                              |

of real engineering problems; define the basic data required to communicate with other professions;  
 4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.  
 Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.  
 Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

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| 2.1 | internal combustion engines | 1087 | obligatory | <b>IC Engine Design 1</b>                      | 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. | 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.                                       |
| 2.2 | internal combustion engines | 1436 | obligatory | <b>Internal Combustion Engine Mechatronics</b> | Acquisition of basic theoretical and practical knowledge in the field of application of mechatronic systems in internal combustion engines. Gaining experience in the operation and application of sensors and actuators in mechatronic systems of modern engines. Closer acquaintance with the structure of                                                                                                                                                     | Student through this course: Acquires and combines specific professional knowledge in the field of mechanical engineering and electronics. Complements knowledge in the field of engine management as a highly dynamic object. He is trained to form and complete a mechatronic system for the internal combustion engine. Masters the basics of the software development and |

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|     |                                    |      |            |                                    | electronic control units (ECU) of modern engines and the specifics of the architecture and functions of microcontrollers, management principles and methods of development and testing of software intended for ECU.                                                                                                                                                                                                                                  | programming process for the ECU. Masters basic data transfer techniques using ECU communication interfaces.                                                                                                                                                                                                                                                                                                                                                 |
| 2.3 | internal combustion engines        | 0856 | obligatory | <b>Supercharging of IC Engines</b> | 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 occurring in intercooler. Broadening knowledge in machine design by studying specific issues of turbocharger design principles. | 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. |
| 2.4 | physics and electrical engineering | 1324 | elective   | <b>Electronics</b>                 | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.                                    | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                          |
| 2.4 | hydropower engineering             | 1001 | elective   | <b>Turbomachinery</b>              | Theoretical background in turbomachinery basic principles. Practical, engineering knowledge in turbomachinery                                                                                                                                                                                                                                                                                                                                         | Upon successful completion of this course, students should be able to:<br>1. identify and describe the various types and                                                                                                                                                                                                                                                                                                                                    |

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|     |                                                                    |      |          |                     | and their applications, with focus on rotodynamic pumps, fans and turbocompressors.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <p>constructions of turbomachinery, as well as the principles of their work,</p> <ol style="list-style-type: none"> <li>2. calculate and apply dimensionless parameters (characteristic coefficients),</li> <li>3. determine the duty point of the hydraulic turbomachine and system,</li> <li>4. select the appropriate pump or fan, as well as the most energy efficient way of their regulation,</li> <li>5. calculate the pump duty point in terms of cavitation,</li> <li>6. calculate the thermodynamic and energy parameters of the turbocompressor,</li> <li>7. plan the fan testing according to the international standard.</li> </ol>                                                                                                                                                                                                                                                                                           |
| 2.4 | engineering materials and welding, tribology, fuels and combustion | 0971 | elective | <b>Combustion M</b> | <p>The objective of the course is for the student to:</p> <p>acquire basic knowledge about the importance of the combustion process; understand the different definitions of the combustion process; understand the physical and chemical processes that take place during combustion; perceive the most important laws that apply to combustion processes; perceive the thermodynamic basics of the combustion process; understand the material and energy balance of the combustion process; understand the basics of chemical statics and kinetics of thermal processes; perceive the types of chemical reactions that occur in combustion processes; understand the rate of chemical reaction and the influencing</p> | <p>After successfully passing the exam in this course, the student will be able to:</p> <p>calculate the material and heat balance of the combustion process; determine the types of chemical reactions important for the combustion process; define the most important kinetic parameters for the considered chemical reactions; determine the thermal effect of chemical reactions; perform an analysis of influencing parameters on the development of chemical reactions and kinetic parameters; perceive the methods of fuel ignition and the spread of the flame front; application of available flame stabilization techniques; master flame testing techniques; perform an analysis of the efficiency of the combustion process; make a choice of technology and devices for combustion with the aim of meeting the energy and environmental characteristics; know how to apply available combustion process models; perform a</p> |

parameters; understand the occurrence of chemical equilibrium, its importance in the analysis of the development of chemical reactions and influential parameters; understand the thermal effects of chemical reactions; perceive the thermochemical laws; perceive the physical and physical-chemical phenomena in the combustion process (fuel and oxidizer mixing mechanisms, adsorption and absorption, diffusion); acquire basic knowledge about modeling the combustion process; perceive the classification of the combustion process according to different criteria; understand the processes of ignition, flame propagation and stabilization of the flame front; understand the phenomena and specifics of combustion of gaseous, liquid and solid fuels; review technologies and devices for combustion of gaseous, liquid and solid fuels; understand the formation of toxic components during the combustion process and ways to reduce air pollution.

comparison and analysis of the combustion process based on experimental results and modeling results; carry out the determination of toxic components produced during combustion; choose the best technology for reducing the emission of toxic components; perform an analysis of the impact of the combustion process on the environment.

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| 2.4 | internal combustion engines | 1478 | elective | <b>Sensors and Computer Based Measurements</b> | <p>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 to the world of virtual instrumentation and graphical</p> | <p>Ability to integrate sensors and DAQ hardware in measurement chains in order to fulfill specific requirements in the field of mechanical engineering system testing &amp; measurements. Ability to build and test software applications (LabVIEW virtual instruments) for measurement and automation of various mechanical engineering systems. Practical knowledge in computer-based measurements of</p> |
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|     |                        |      |          |                                         | programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in 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 development and testing. | fundamental engineering data. Supplied basic knowledge and practice in the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 2.5 | fluid mechanics        | 1011 | elective | <b>Gas Dynamics</b>                     | <p>The student should:</p> <ol style="list-style-type: none"> <li>1. acquire basic theoretical knowledge in the field of gas dynamics;</li> <li>2. be trained to perform basic engineering calculations of compressible flows;</li> <li>3. become familiar with the basic procedures for experimental research in gas dynamics.</li> </ol>              | 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.                                                                                                                                                                                                                 |
| 2.5 | hydropower engineering | 1425 | elective | <b>CFD Modelling of Turbo-machinery</b> | The knowledge of engineering numerical design of turbomachines. Ability to work in design and development offices in the turbomachinery industry. Ability to innovate design methods, as well as to acquire the basis for academic development in terms of the application of computational fluid mechanics.                                            | <p>Upon successful completion of this course, students will be able to:</p> <ol style="list-style-type: none"> <li>1. apply different procedures for designing turbomachines,</li> <li>2. compare geometric and energy characteristics of turbomachines obtained by applying different calculation approaches,</li> <li>3. perform engineering calculations, using modern software for geometry construction (CAD) and flow calculation (CFD) in turbomachines,</li> <li>4. have the skill to work in a computer environment,</li> <li>5. analyze and present the obtained calculation results.</li> </ol> |

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| 2.5 | thermomechanics | 1451 | elective | <b>Heat transfer</b> | <p>Students should gain basic theoretical and professional knowledge and skills that will enable them to independently recognize and solve a moderately complex multidimensional stationary and transient heat transfer problems that faced by engineers of thermo-technique, thermo-energetic and processes engineering.</p> | <p>After successful completion of this course students should be able to:</p> <ol style="list-style-type: none"> <li>1) describe and explain the physical essence and mechanisms and express the basic hypotheses and laws that describe the processes of heat transfer: steady and unsteady heat conduction, natural and forced heat convection with and without changing phase state (boiling and condensation) and heat radiation of gases and vapors,</li> <li>2) calculate the temperature field and heat flow in solid bodies, especially rods, ribs and ribbed surfaces on the basis knowledge of the boundary and initial conditions in case of steady heat conduction</li> <li>3) calculate the temperature field in simple geometric solid bodies in case of unsteady heat conduction with the change the aggregate state - the melting and solidification</li> <li>4) calculate the local and average values the coefficient of heat transfer, ie. heat flux in case free and forced convective heat transfer for fluid flows across, through and around solid bodies but without changing its phase state,</li> <li>5) calculate the heat flux, mass flow and thickness of the layer of condensate in case convective heat transfer during condensation of steam on the vertical and inclined solid surface,</li> <li>6) calculate the heat flux, mass flow and thickness of the layer of condensate in forced flow condensation of steam on the vertical and inclined solid surface,</li> <li>7) calculate the radiation heat flux from semi-transparent absorbing gases on opaque gray</li> </ol> |
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|     |                             |      |            |                              | surfaces and the radiation heat flux from semi-transparent absorbing gases with solid particles on opaque gray surfaces.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2.5 | control engineering         | 0599 | elective   | <b>Industrial Automation</b> | <p>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.</p> <p>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.</p>                                                                                                                                                                                        |
| 3.1 | internal combustion engines | 1089 | obligatory | <b>IC Engine Design 2</b>    | <p>Acquiring new knowledge on role and design features of IC Engine Auxiliary systems - engine cooling &amp; 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.</p> <p>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</p> <p>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.</p> |

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|     |                             |      |            |                                        | torsional silencers.<br>Specific design of two-stroke engines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                         |
| 3.2 | internal combustion engines | 0860 | obligatory | <b>IC Engine Testing</b>               | 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. | 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                                                    |
| 3.3 | internal combustion engines | 1024 | obligatory | <b>Ecology of Mobile Power Sources</b> | 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.                               | 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. |

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| 3.3 | internal combustion engines | 1479 | obligatory | <b>Engine Design Project</b>              | Gaining experience through practical work on the design of IC engines. The practical application of knowledge from previous IC engine 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 design methods in mechanical engineering, especially in the field of IC engines. Understanding and gaining practical experience working with computer-aided design and calculation methods (CAD - 2D, 3D, CAE). | Understanding complex mechanical structures, the connection of individual parts and components, and the ability to design functional and well-designed machines. The ability to practically apply modern software tools for designing in mechanical engineering. The capability to design, making good material and production methods selection of the most essential parts of internal combustion engines. Selection and dimensioning of auxiliary systems and components needed for proper engine functioning.                                                                                                                                                                                                                              |
| 3.4 | fluid mechanics             | 1559 | elective   | <b>Computational Fluid Dynamics (CFD)</b> | 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.                                                                                                                                                                                                                                                                                                     | <p>Upon successful completion of the course, students will be able to:</p> <ul style="list-style-type: none"> <li>- explain the general principles of numerical solution of governing equations for fluid flow</li> <li>- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow</li> <li>- explain and apply principles of numerical grid generation</li> <li>- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)</li> <li>- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in</li> </ul> |

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|     |                                                                    |      |          |                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <p>various domains</p> <ul style="list-style-type: none"> <li>- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 3.4 | engineering materials and welding, tribology, fuels and combustion | 0519 | elective | <b>Tribology</b>             | <p>The student attending this course should:</p> <ul style="list-style-type: none"> <li>• 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;</li> <li>• 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;</li> <li>• Solve problems related to the prevention of wear and competently decide on techniques to improve tribological properties of materials and lubrication technologies.</li> </ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"> <li>• Identifies and critically analyze the basic causes of energy and material dissipation in some mechanical system;</li> <li>• Recognize the dominant type of wear in some mechanical system and to propose appropriate measures for its reduction;</li> <li>• Choose the appropriate type of material for the basic tribological elements (plain bearings, roller bearings and gears);</li> <li>• Describes and distinguishes the most common surface modification and coating deposition methods;</li> <li>• Explain the influences of temperature and pressure on the value of the viscosity (lubricants rheology);</li> <li>• Describes and distinguishes the basic types and methods of lubrication with their characteristics.</li> </ul> |
| 3.4 | engineering materials and welding, tribology, fuels and combustion | 1146 | elective | <b>Ecology of combustion</b> | <p>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</p>                                                                                                                                                                                                                                                                                                                                                           | <p>After successful finishing the course students should be able to:</p> <ul style="list-style-type: none"> <li>- recognize and use modern technologies of the combustion processes,</li> <li>- use techniques for reduction of emission of harmful and polluting combustion products,</li> <li>- apply the acquired knowledge in combustion in the industry and energy sectors,</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|     |                             |      |          |                                        | better understanding of the topic, train and qualify students to become competent experts in this field of international key importance.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | - work in research and development organizations.                                                                                                                                                                                                                                                                                                                                                                                             |
| 3.4 | internal combustion engines | 1026 | elective | <b>Selected topics in IC Engines 1</b> | 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. | 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.                                                                                       |
| 3.5 | thermal power engineering   | 0336 | elective | <b>Turbocompressors</b>                | <ol style="list-style-type: none"> <li>1. The achievement of academic competence in the field of compressors and thermal power plant engineering.</li> <li>2. Mastery of theoretical knowledge about how to transform mechanical work into internal energy of fluid by learning of thermodynamic processes and equipment.</li> <li>3. The acquisition of practical skills for design and optimization of</li> </ol>                                                                                                                                                                                                                                                                                         | <p>On completion of this programme, it is expected that student will be able to:</p> <ul style="list-style-type: none"> <li>• perform design of a multistage axial compressor writing own program code,</li> <li>• select dimensionless parameters of compressor stages,</li> <li>• apply one-dimensional theory of the compressor stage, determine the main dimensions of the stage, calculate efficiency and the stage operating</li> </ul> |

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|     |                                                                    |      |          |                             | turbocompressors.<br>4. Mastering the techniques of process modeling.                                                                                                                                                                                                                                                                                                                                                                                                                                                   | parameters,<br><ul style="list-style-type: none"> <li>• apply the appropriate solutions of 3D flow and define 3D blade geometry of the compressor stage</li> <li>• select the type of aero profile, calculate the aerodynamic losses and deviation</li> <li>• define the meridian flow path of the entire machine</li> <li>• apply different control modes for the turbocompressor</li> <li>• analyse compressor behavior at off-design operating parameters.</li> </ul>                                                                                                                                                                                                                                                                                       |
| 3.5 | process and environmental protection engineering                   | 1549 | elective | <b>Heat exchangers</b>      | Analysis of heat transfer operations and apparatus and their role in modern industry. Getting to know the most commonly used types of heat transfer apparatuses - their construction and calculation procedures.                                                                                                                                                                                                                                                                                                        | Mastering the calculation procedures required for the analysis of heat transfer operations - creating a heat balance, determining the operating line and driving force. Mastering the calculation procedures required for sizing the most commonly used heat exchangers.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 3.5 | engineering materials and welding, tribology, fuels and combustion | 0537 | elective | <b>Tribological systems</b> | The student attending this course should: <ul style="list-style-type: none"> <li>• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);</li> <li>• Master the calculation methods for tribological elements using the modern lubrication theories;</li> <li>• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.</li> </ul> | Based on the mastered knowledge the student is qualified to: <ul style="list-style-type: none"> <li>• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;</li> <li>• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;</li> <li>• Propose the solutions for problems originate from the friction and wear process;</li> <li>• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;</li> <li>• Applies methods for the calculation of working and tribological characteristics of considered</li> </ul> |

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|     |                             |      |            |                                        | tribological system;<br>• Select materials, lubricants and lubrication mode for the considered tribological systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 3.5 | internal combustion engines | 1027 | elective   | <b>Selected topics in IC Engines 2</b> | <p>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 through acquaintance with the state-of-the-art tools and techniques.</p> <p>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.</p> |
| 4.1 | internal combustion engines | 1480 | obligatory | <b>Skill praxis M - MOT</b>            | <p>Acquiring practical knowledge of a mechanical engineer's duties. Gaining knowledge about company structure, management and the quality assurance system. Practical knowledge of manufacturing processes and corresponding machine tools. Broadening and acquiring new knowledge in the fields of IC engines research and testing.</p> <p>Understanding the organizational structure and the mutual connections and relationships of individual units within a company. Understanding the importance of teamwork in engineering practice. Gaining practical skills in the field of CAD/CAE/CAM. Acquiring the ability to use modern measuring equipment and software in the field of engine testing.</p>                                                                                                                                                                                                                                                                                                                                                                         |
| 4.3 | -                           | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>          | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; understanding the principles of project and equipment design and the</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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.

- based on knowledge in sciences, engineering sciences and information technologies;
- Design a system, component or process and respond to specified needs;
  - Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;
  - Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;
  - Apply standard tests and measurements: conduct, analyse and interpret the results;
  - Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;
  - Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;
  - Consider different solutions critically and self-critically;
  - Apply the acquired knowledge in practice;
  - Adapt to newly arising situations in practice.

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4.4      -                      1503      obligatory      **M.Sc. Thesis**

The preparation of M.Sc. 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 thesis.

- Upon the successful defense of the M.Sc. thesis, engineers should be able to:
- Present the results of independent work in written form;
  - Create documentation in accordance with technical standards;
  - Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;
  - Communicate efficiently with the engineering



## Material Handling, Constructions and Logistics

| position | department                                    | ID   |            | title                                                      | goal                                                                                                                                                                                                                                                                                                                                                                                     | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
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| 1.1      | material handling, constructios and logistics | 0187 | obligatory | <b>Facility layout and industrial logistics</b>            | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Make a project requirement for factory, factory facilities, transport, storage and logistic systems planning.</li> <li>- Make a calculation of needed technological and additional equipment, working power, working places, needed areas and material flow.</li> <li>- Make a layout of the factory, factory facilities, transport, storage and logistic systems.</li> <li>- Calculate the basic elementary subsystems performances (by queueing systems modeling) of the factory, factory facilities, transport, storage and logistic systems.</li> <li>- Make a cast iron foundry concept study.</li> </ul> |
| 1.2      | material handling, constructios and logistics | 0909 | obligatory | <b>Computer Aided Design in Material Handling Practice</b> | 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.                                                                                                                         | <p>After the completion of the course, student is trained to:</p> <ul style="list-style-type: none"> <li>•Apply the finite element method (FEM), with linear finite elements, in formulation and calculation of plane trusses and frames</li> <li>•Perform static analysis of plane truss and frame in FEM software and work and present basic technical report for given engineering problem</li> <li>•Form the 3D structural model with linear finite elements and give static analysis due to loads</li> <li>•Use different FEM software for structural analysis</li> <li>•Do the basic design of gantry crane according to engineering recommendations</li> </ul>                                                                 |

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| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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.</p>                                                                                                                                                     |

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.</p> <p>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p>                                                                                                                                                                          | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |

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| 1.5 | engineering materials and welding, tribology, fuels and combustion | 0899 | elective | <b>Welding processes M</b> | <p>The aim of this course is for students to become competent in the area of welding. This course is designed to provide information through theoretical lectures, computational classes and seminar papers, but also through welding workshop practice. They should also develop appropriate academic skills needed for the profession and become informed with the specificity of each welding process and appropriate equipment.</p> | <p>Upon the successful completion of the course, the students are able to:</p> <ul style="list-style-type: none"> <li>-Detail the differences between welding processes according to their characteristics</li> <li>-Detail the rang of application, appropriate joint preparations and potential problems to be overcome</li> <li>-Understand fully the fundamental physics of an electric arc, including the main parameters influencing arc stability</li> <li>-Explain fully the principles of welding processes including transfer modes and their applications</li> <li>-Explain the purpose and working principle of each component of the equipment</li> <li>-Identify the influence of welding parameters on weld quality</li> <li>-Choose appropriate welding process, power source, parameters and filler material for particular applications and materials</li> <li>-Predict potential hazards and define methods for safe handling of welding equipment</li> </ul> |
| 1.5 | physics and electrical engineering                                 | 0401 | elective | <b>Electric Machinery</b>  | <p>Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines.</p>                                                              | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;</li> <li>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;</li> <li>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;</li> </ol>                                                                                                                                                                                                                                                                                                                                                    |

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|     |                                               |      |            |                                                              |                                                                                                                                                                                                                                                                                                                                                     | <p>4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.</p> <p>Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.</p> <p>Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.</p>                                                                                                                                                                                                 |
| 1.5 | material handling, construction and logistics | 1539 | elective   | <b>Construction, mining and conveying machinery elements</b> | <p>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.</p>                                                               | <p>Goal of this course is to introduce the students to the following skills:</p> <ul style="list-style-type: none"> <li>•Modeling and calculation of unique below-the-hook lifting devices;</li> <li>•Design, modeling and calculations related to fundamental substructures of crawler systems;</li> <li>•Modeling and calculation of bearing structures of mobile construction, transport and mining machines;</li> <li>•Design and calculation of stabilizers;</li> <li>•Computer-aided modeling and creating technical documentation of elements and assemblies of machines used in construction, mining and material handling processes.</li> </ul> |
| 2.1 | material handling, construction and logistics | 0910 | obligatory | <b>Structural and Stress Analysis</b>                        | <p>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.</p> | <p>After the completion of the course, student is trained to:</p> <ul style="list-style-type: none"> <li>•Calculate the shear stresses of the thin-walled closed section, such as on box girder of bridge crane</li> <li>•Calculate first moments of area of the thin-walled open section</li> <li>•Obtain the position of the shear centre of the thin-walled open section and form the warping</li> </ul>                                                                                                                                                                                                                                              |

|     |                                               |      |            |                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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|     |                                               |      |            |                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                 | <p>coordinate</p> <ul style="list-style-type: none"> <li>•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</li> <li>•Perform the complete stress proof of girders made of thin-walled open section</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                      |
| 2.2 | material handling, constructios and logistics | 0119 | obligatory | <b>Transport and logistic systems design</b>    | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Specify elementary subsystems, elementary subsystem variables, elementary subsystem performance variables and environment variables of the flexible transport systems.</li> <li>- Calculate the basic elementary subsystems performance variables (by queueing systems modeling) of the flexible transport and logistic systems.</li> <li>- Make a comparison of different flexible transport system applications.</li> <li>- 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.</li> </ul> |
| 2.3 | material handling, constructios and logistics | 0308 | obligatory | <b>Conveying and Material Handling Machines</b> | <p>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,</p>                                                                       | <p>By completing this course student acquires ability to:</p> <ul style="list-style-type: none"> <li>•determine bulk and solid materials characteristics</li> <li>•determine conveying machine's throughput/capacity in accordance with project requirements and type of conveyed material</li> <li>•calculate and choose conveyor drive</li> <li>•calculate basic parameters and components of</li> </ul>                                                                                                                                                                                                                                                                                                                                                |

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|     |           |      |          |                            | selection of drive units and calculation of the capacity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | belt conveyor <ul style="list-style-type: none"> <li>•calculate basic basic parameters and components of apron conveyor</li> <li>•calculate basic basic parameters and components of screw conveyor</li> <li>•calculate basic basic parameters and components of bucket elevator</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 2.4 | mechanics | 0007 | elective | <b>Mechanics of robots</b> | <p>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.</p> | <ul style="list-style-type: none"> <li>•Determine the number of degrees of freedom of robotic system (RS)</li> <li>•Define the matrix of transformation, in the case of (Euler angles, Rezal angles, Hamilton-Rodrigues parameters, ...)</li> <li>• 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</li> <li>• Forming a kinematic model RS and solve direct and inverse kinematics task of RS</li> <li>• Analyze singular cases in solving the task of kinematics RS</li> <li>• Formed terms of linear momentum, angular momentum and kinetic energy of arbitrary segment RS</li> <li>• 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</li> <li>• Forming the differential equations of motion using the RS covariant form of Lagrange equations of the second kind and solve other types of direct</li> </ul> |

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|-----|--------------------------------------------------------------------|------|----------|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                                                                    |      |          |                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <p>and inverse task of dynamics</p> <ul style="list-style-type: none"> <li>• Numerical simulate the previously formed kinematic / dynamic models using programming environment (MATLAB, Mathematica, etc.)</li> <li>• 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.</li> <li>• Set additional constraint equations in the case of constrained robotic gripper movements</li> <li>• Distinguish non-redundant and redundant RS and determine the degree of redundancy RS</li> <li>• Distinguish the basic concepts of control of RS</li> </ul>  |
| 2.4 | engineering materials and welding, tribology, fuels and combustion | 0719 | elective | <b>Service Properties of Welded Joints</b> | <p>The aim of this course is for students to become competent in the area of the analysis the current state of metal during service as well as failure and fracture of welded joints. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing.</p> | <p>Upon the successful completion of the course, students are able to:</p> <ul style="list-style-type: none"> <li>- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;</li> <li>- determine the potential causes of damage;</li> <li>- perceive the eventual possibilities for preventing the occurrence of damage;</li> <li>- define the testing programme for detecting damages in mechanical structures;</li> <li>- prescribe maintenance measures for preventing damage in mechanical structures;</li> <li>- relate the acquired knowledge to other fields, with practical applications.</li> </ul> |
| 2.4 | mechanics                                                          | 0037 | elective | <b>Theory of Mechanical Vibrations</b>     | <p>It is necessary to enable the students to independently form and solve linear differential equations of motion of mechanical models of real objects</p>                                                                                                                                                                                                                                                                                                                                                                              | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>• Determine equilibrium position of conservative</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

oscillatory moving in different areas of mechanical engineering.

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.

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| 2.5 | industrial engineering | 1370 | elective | <b>Design of logistic and warehouse</b> | Achieving competency and academic skills in the process of industrial system design. | Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of |
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|     |                        |      |          | <b>systems</b>                                         | 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.                                                                                                                                                                                                                                                                                                          | 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.                                                                                                                                                                                                                                                                                                                                                                                                      |
| 2.5 | production engineering | 0722 | elective | <b>Computer Simulation in Manufacturing Automation</b> | 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. | After successfully completing this course, the students should be capable to: <ul style="list-style-type: none"> <li>- Create and implement stochastic simulation;</li> <li>- Create conceptual model for discrete event simulation;</li> <li>- Create and implement discrete event simulation within fixed and flexible automation framework;</li> <li>- Create conceptual and computer model for continuous simulation of various processes;</li> <li>- Integrate continuous and discrete event simulation;</li> <li>- Manage discrete event simulation project.</li> </ul> |
| 2.5 | motor vehicles         | 0874 | elective | <b>Vehicles and Environment</b>                        | 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                                                                                                                                                                                                                                                                            | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>- Explain the concept of fuel consumption and the possibilities for its reduction;</li> <li>- Analyze the impacts of driver on fuel consumption;</li> <li>- Identify and explain the harmful elements of the exhaust emissions of motor vehicles, ways of their formation and effects, methods of measurement</li> </ul>                                                                                                                                        |

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|     |                                               |      |            |                                                              | analysis of these effects in this case are a prerequisite for creating a modern engineer, not only in the field of motor vehicles.                                                                                                                                                                                | <p>and legal constrain values per component;</p> <ul style="list-style-type: none"> <li>- Identify alternative vehicle drives and fuels;</li> <li>- Analyze working principles of hybrid and electric vehicles;</li> <li>- Explain the impact of noise and vibration produced by vehicle;</li> <li>- Recognize environmentally friendly and modern materials used in the design and manufacture of vehicles;</li> <li>- Describe the recycling process and the life cycle of the vehicle.</li> </ul>                                                                                                                                                                                                                                                                                                                          |
| 2.5 | material handling, constructios and logistics | 1540 | elective   | <b>Design of construction and mining machines subsystems</b> | 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. | <p>This course offers the following skill set to the students who complete it:</p> <ul style="list-style-type: none"> <li>•Design of backhoe excavators’ working devices;</li> <li>•Design of basic elements of single-bucket excavators’ working devices;</li> <li>•Modeling and calculation of a bucket wheel excavator’s working device – bucket wheel body and buckets;</li> <li>•Design and calculation of the bucket wheel drive system;</li> <li>•Design and calculation of four and eight-wheel bogie of a crawler mechanism;</li> <li>•Calculation of basic technical and technological parameters, power and strength of jaw and conic rock crushers;</li> <li>•Load analysis, modeling, proper supporting, loading and finite element analysis of civil and mining machines’ fundamental subassemblies.</li> </ul> |
| 3.1 | material handling, constructios               | 1541 | obligatory | <b>Mining and Construction Machines</b>                      | Basic course goals (objectives): 1) introducing students with specificities of working process, design, modeling and                                                                                                                                                                                              | By successfully completing this course the student should be able to competently assess the following problems:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

and logistics

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.

- 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.

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| 3.2 | material handling, constructios and logistics | 0139 | obligatory | <b>Cranes Design</b> | 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. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>•identify, classify and analyze regular, occasional and exceptional load at overhead travelling cranes</li> <li>•perform calculation and selection of the bridge crane geometry</li> <li>•determine the load of the bridge crane in characteristic cross section</li> <li>•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</li> <li>•perform calculation and choose stiffnesses</li> </ul> |
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|     |                                                |      |            |                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <ul style="list-style-type: none"> <li>•perform calculation of end carriages</li> <li>•carry out the verification of the analytical calculation with the results obtained in the FEM software package</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 3.3 | material handling, constructions and logistics | 0127 | obligatory | <b>Eco Design</b>               | 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.                                                                            | <p>By completing this course student acquires ability to:</p> <ul style="list-style-type: none"> <li>•analyse life cycle of a product using tools for life cycle assessment</li> <li>•implement ecodesign strategies into design process and product development</li> <li>•suggest measures for improvement of environmental performances of the product</li> <li>•implement legislative in the field of ecology into design process</li> <li>•design and develop sustainable product</li> </ul>                                                                                                                                                 |
| 3.4 | weapon systems                                 | 1562 | elective   | <b>Hybrid technical systems</b> | Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical requirements as part of a complex system or the system as a whole</li> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul> |

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| 3.4 | material handling, construction and logistics | 1542 | elective | <b>Fundamentals of Mining and Construction Machines Dynamics</b> | 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.                                                                                    | By successfully completing this course the student should acquire the following competences: <ul style="list-style-type: none"> <li>• Properly forming the reduced dynamic models of earthmoving machines such as single-bucket excavators and bulldozers;</li> <li>• 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;</li> <li>• 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;</li> <li>• Creating dynamic models of continuous excavators' substructures;</li> <li>• Identification and analysis of continuous excavators' substructures response to excitation caused by resistance to excavation;</li> <li>• Calculation and proper selection of basic parameters of conveyor belts with relatively high conveyor speed, dominantly used in mobile continuous earthmoving machines.</li> </ul> |
| 3.4 | general machine design                        | 1444 | elective | <b>Technical regulations and standards</b>                       | Acquiring of the 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. | After the attended course, students gain knowledge about: <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

and health at work.

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| 3.5 | agricultural engineering                                           | 1456 | elective | <b>Plant design for food production and processing</b> | <p>1. Master the theoretical foundations of the design of machinery, equipment and technological lines for manufacturing and food processing; 2 Getting to know your limitations and the specific production lines and food processing; 3 Introduction to the principles of the design of machinery and equipment manufacturing and food processing; 4 Acquire practical skills in analyzing the set of engineering problems and its solving multidisciplinary approach.</p>                                               | <p>After successful completion of this course, studenty should be able to:</p> <ul style="list-style-type: none"><li>• Define the project management plan,</li><li>• Describe the production technology and food processing,</li><li>• Select the appropriate machinery and equipment for the design of complete lines and factories for processing agricultural products,</li><li>• Design complete line and / or factory for the production, processing and storage of agricultural products,</li><li>• Estimates of the outcomes of the project in relation to the initial request,</li><li>• Estimates energy required for food processing,</li><li>• Be efficient in teamwork,</li><li>• Estimates of economic analysis,</li><li>• Preparing and exposing projects to potential investors.</li></ul> |
| 3.5 | engineering materials and welding, tribology, fuels and combustion | 0537 | elective | <b>Tribological systems</b>                            | <p>The student attending this course should:</p> <ul style="list-style-type: none"><li>• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);</li><li>• Master the calculation methods for tribological elements using the modern lubrication theories;</li><li>• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.</li></ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"><li>• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;</li><li>• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;</li><li>• Propose the solutions for problems originate from the friction and wear process;</li><li>• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;</li></ul>                                                                                                                                                   |

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|     |                                 |      |            |                             |                                                                                                                                                                                                                                                                                          | <ul style="list-style-type: none"> <li>• Applies methods for the calculation of working and tribological characteristics of considered tribological system;</li> <li>• Select materials, lubricants and lubrication mode for the considered tribological systems.</li> </ul>                                                                                                                                                                                                                                                                                                                                                        |
| 3.5 | motor vehicles                  | 0876 | elective   | <b>Forensic Engineering</b> | Student is enabled to apply forensic engineering methods, particularly in the area of motor vehicles, which comprises analyses and reconstruction of road accidents. Analogous methods will be applied in other fields of mechanical engineering, depending on the interest of students. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- explain the concept of forensics and forensic engineering, with respect to vehicles;</li> <li>- define and analyze technical system failures, their causes and effects, with a special emphasis on the application in automotive field;</li> <li>- identify and analyze the causes of traffic accidents in which vehicles participated, with elements of investigation and reconstruction;</li> <li>- analyze adequate technical solutions and conditions under which accidents might be avoided.</li> </ul> |
| 3.5 | hydropower engineering          | 1423 | elective   | <b>Pumps and fans</b>       | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.              | <p>Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.</p>                            |
| 4.1 | material handling, constructios | 1410 | obligatory | <b>Skill praxis M - TKL</b> | The aim of the course is to acquaint students with tools, machines and devices in the field of mechanization used in                                                                                                                                                                     | By mastering the program of the course, students get acquainted with: 1. Production processes in companies that produce or use equipment for                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

and logistics

various branches of the economy, especially in industry, construction, mining, logistics, transport, tourism, energy, process engineering, service activities, etc

mechanization and material handling, 2. Material Handling and Conveying, 3. Processes of maintenance of equipment and machinery for mechanization and material handling, etc.

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| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> | <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"><li>• Identify, formulate, analyse and solve complex engineering problems;</li><li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li><li>• Design a system, component or process and respond to specified needs;</li><li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li><li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li><li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li><li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li><li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li><li>• Consider different solutions critically and self-critically;</li><li>• Apply the acquired knowledge in practice;</li><li>• Adapt to newly arising situations in practice.</li></ul> |
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| 4.4 | - | 1503 | obligatory <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> | <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |
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## Mechanical Engineering & Information Technology

| position | department               | ID   |            | title                           | goal                                                                                                                                                                                                                                                                                                                                                                                                                           | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| 1.1      | information technologies | 1489 | obligatory | <b>C/C++</b>                    | Introduce to C/C++; Structure of C/C++ and usability. Solving simple problems in mechanical engineering using C/C++. Art of pointers. Saving acquisition data in files, use that files and discuss results.                                                                                                                                                                                                                    | After successful completion of the program provided for in this case the student can:<br>Program 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.                                                                                                                                                                                                                                                                                           |
| 1.2      | information technologies | 1490 | obligatory | <b>Object oriented paradigm</b> | 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.                                                                         | With acquired knowledge student can: Recognize the conditions for using object-oriented design and programming methodology, Design simple user class and link them with the system classes, Design simple methods by using system design methods, Use the programming languages C++ and Java.                                                                                                                                                                                                                                                                                                                       |
| 1.3      | mechanics                | 0004 | elective   | <b>Mechanics M</b>              | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body</li> </ul> |

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|     |                                   |      |          |                          |                                                                                                                                                                                                                                                                                                                                                            | <p>motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</p> <ul style="list-style-type: none"> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 1.3 | fluid mechanics                   | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                      | <p>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.</p> |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>      | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p> | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                               |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b>  | <p>Student should gain knowledge in thermodynamics and thermal devices and plants that are present in process</p>                                                                                                                                                                                                                                          | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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|     |                        |      |          |                                       | <p>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.</p> | <p>Second principle of thermodynamics to the closed and open thermodynamic systems.</p> <ul style="list-style-type: none"> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |
| 1.5 | industrial engineering | 0523 | elective | <b>Management Information Systems</b> | <p>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.</p>                                    | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Use software tools for decision support,</li> <li>- Design models for decision-making process in DSS tools,</li> <li>- Using expert systems in the field of industrial engineering,</li> <li>- Projected base of knowledge in expert systems,</li> <li>- Estimates of efficiency designed models in the specific case study.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 1.5 | mathematics            | 0354 | elective | <b>Probability and</b>                | <p>Introduction to techniques of probability</p>                                                                                                                                                                                                                                                                                                                                                                                | <p>Upon successful completion of this course, students</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

**statistics**

theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.

should be able to:

- 1) Calculate probability and conditional probability of random events.
- 2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.
- 3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.
- 4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.
- 5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.
- 6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | information technologies | 1303 | elective | <b>Computer Networks</b> | <p>Course objective:</p> <ul style="list-style-type: none"><li>• Introduction to the concept, standard tasks and operation of computer networks.</li><li>• Introduction to the protocol and other factors that control, manage and participate in creating a variety of processes and resources of computer</li></ul> | <p>The acquired knowledge allows students:</p> <ul style="list-style-type: none"><li>• to identify and suggest the type of computer network,</li><li>• to understand the problems that arise whendesigning computer networks,</li><li>• to create a project of computer network that includes a sugestion purchase of necessary equipment.</li></ul> |
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networks and computers.

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| 2.1 | information technologies | 1491 | obligatory | <b>Algorithms and data structures</b>           | <ul style="list-style-type: none"> <li>• Basic facts of algorithm theory.</li> <li>• Abstract data type and basic implementation.</li> <li>• Data structures in mechanical engineering.</li> <li>• Using standard algorithms in solving simple problems in mechanical engineering.</li> </ul>                                                                   | After successful completion of the program provided for in this case the student can: <ul style="list-style-type: none"> <li>• To find data structure to solve the problem.</li> <li>• Use data structures and standard algorithms in solving simple problems in mechanical engineering.</li> <li>• To find suboptimal algorithm to solve simple problems in mechanical engineering.</li> <li>• To use standard algorithms to solve complex problems in mechanical engineering.</li> </ul>                          |
| 2.2 | information technologies | 1492 | obligatory | <b>Programmable Control Systems</b>             | 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. | 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.                                   |
| 2.3 | information technologies | 1493 | obligatory | <b>Data Exquisite in Mechanical Engineering</b> | <p>Course objective:</p> <ul style="list-style-type: none"> <li>• Numerical and mathematical analysis capabilities for each measurement.</li> <li>• Design and write programs for analyzing measurements.</li> <li>• Comparison analysis of numerical data processing and analysis software.</li> <li>• Implementation of PHP and JAVA Script.</li> </ul>       | <p>The acquired knowledge allows:</p> <ul style="list-style-type: none"> <li>• That be entered professional do the measurements and determine the necessary and forward the required size,</li> <li>• That the measurement is so mathematical, numerical and statistical analysis and then to be graphical and logical preparation for further analysis,</li> <li>• That, using PHP or Java Script, or both, make software to perform accurate data processing which is a pre-determined mathematically.</li> </ul> |

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| 2.4 | engineering materials and welding, tribology, fuels and combustion | 0971 | elective | <b>Combustion M</b> | <p>The objective of the course is for the student to:</p> <p>acquire basic knowledge about the importance of the combustion process; understand the different definitions of the combustion process; understand the physical and chemical processes that take place during combustion; perceive the most important laws that apply to combustion processes; perceive the thermodynamic basics of the combustion process; understand the material and energy balance of the combustion process; understand the basics of chemical statics and kinetics of thermal processes; perceive the types of chemical reactions that occur in combustion processes; understand the rate of chemical reaction and the influencing parameters; understand the occurrence of chemical equilibrium, its importance in the analysis of the development of chemical reactions and influential parameters; understand the thermal effects of chemical reactions; perceive the thermochemical laws; perceive the physical and physical-chemical phenomena in the combustion process (fuel and oxidizer mixing mechanisms, adsorption and absorption, diffusion); acquire basic knowledge about modeling the combustion process; perceive the classification of the combustion process</p> | <p>After successfully passing the exam in this course, the student will be able to:</p> <p>calculate the material and heat balance of the combustion process; determine the types of chemical reactions important for the combustion process; define the most important kinetic parameters for the considered chemical reactions; determine the thermal effect of chemical reactions; perform an analysis of influencing parameters on the development of chemical reactions and kinetic parameters; perceive the methods of fuel ignition and the spread of the flame front; application of available flame stabilization techniques; master flame testing techniques; perform an analysis of the efficiency of the combustion process; make a choice of technology and devices for combustion with the aim of meeting the energy and environmental characteristics; know how to apply available combustion process models; perform a comparison and analysis of the combustion process based on experimental results and modeling results; carry out the determination of toxic components produced during combustion; choose the best technology for reducing the emission of toxic components; perform an analysis of the impact of the combustion process on the environment.</p> |
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|     |                          |      |          |                                                      | <p>according to different criteria; understand the processes of ignition, flame propagation and stabilization of the flame front; understand the phenomena and specifics of combustion of gaseous, liquid and solid fuels; review technologies and devices for combustion of gaseous, liquid and solid fuels; understand the formation of toxic components during the combustion process and ways to reduce air pollution.</p>                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 2.4 | information technologies | 1448 | elective | <b>Distributed Systems in Mechanical Engineering</b> | <ul style="list-style-type: none"> <li>• Introduction to the paradigm of distributing data</li> <li>• Knowledge of basic protocols for the transfer and sharing of distributed data.</li> <li>• Designing local area networks based on different technologies</li> <li>• Introduction to multiprocessor distributed systems in the automotive and aircraft industry</li> <li>• Introduction to algorithms that are typical of multi-processor distributed systems</li> </ul> | <p>Стечено знање омогућава студенту:</p> <ul style="list-style-type: none"> <li>• to recognize the conditions for the formation of local area networks</li> <li>• to allocate names to resources on the net</li> <li>• to control and manage assigned resources</li> <li>• to understand the multi-processor and redistribution of data among them</li> </ul>                                                                                         |
| 2.4 | industrial engineering   | 0513 | elective | <b>Risk management in Terotechnology</b>             | <p>The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to apply production and maintenance systems based on risk management, due to knowledge in the identification, analysis, risk assessment and decision-making on the basis of those facts.</p>                                                                                                                                                                  | <p>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</p> |

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.

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| 2.5 | strength of structures | 0721 | elective | <b>Basics of Composite Materials Mechanics</b> | <p>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.</p> | <ol style="list-style-type: none"> <li>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.</li> <li>2. Students will learn how to perform stress – strain analysis of laminate composite materials.</li> <li>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.</li> <li>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</li> </ol> |
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techniques.

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| 2.5 | information technologies | 1494 | elective | <b>Embedded systems and IoT in mechanical engineering</b> | Acquisition of theoretical and practical knowledge in the field of embedded systems and Internet of Things.                                                                                                                                                                                                                                                                                                                                         | Students are trained for practical work with embedded systems in the Internet environment. Students have theoretical knowledge of Internet architecture and embedded systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 2.5 | motor vehicles           | 0874 | elective | <b>Vehicles and Environment</b>                           | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>- Explain the concept of fuel consumption and the possibilities for its reduction;</li> <li>- Analyze the impacts of driver on fuel consumption;</li> <li>- 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;</li> <li>- Identify alternative vehicle drives and fuels;</li> <li>- Analyze working principles of hybrid and electric vehicles;</li> <li>- Explain the impact of noise and vibration produced by vehicle;</li> <li>- Recognize environmentally friendly and modern materials used in the design and manufacture of vehicles;</li> <li>- Describe the recycling process and the life cycle of the vehicle.</li> </ul> |
| 2.5 | aerospace engineering    | 0311 | elective | <b>Avionics</b>                                           | 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.                                                                                                                                                                      | 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.

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| 3.1 | information technologies | 1495 | obligatory | <b>Engineering Software Design</b> | <p>Prepare inputs for the engineering software based on standard calculations.</p> <ul style="list-style-type: none"> <li>• Preparation of engineering calculations for effective programming and obtain efficient programs.</li> <li>• Testing and verification of software engineering. Validation of software engineering.</li> <li>• Use SQL to get information from databases.</li> <li>• Use SQL for engineering decision making.</li> <li>• Organization, normalization of data in the database.</li> <li>• Privacy, data archiving. Issues of software licensing.</li> </ul> | <p>After successful completion of the program provided for in this case the student can:</p> <ul style="list-style-type: none"> <li>• Prepare a budget for programming.</li> <li>• to assess the quality of information obtained from the input data that are processed program written for a defined budget.</li> <li>• use the database for specific problems in mechanical engineering.</li> <li>• use SQL as a generator of low-level information for software engineering.</li> </ul>                                                                                                                                                                                                                                                                                   |
| 3.2 | information technologies | 1449 | obligatory | <b>Optimization Methods</b>        | <p>The main goal of this course for the student is to give the necessary knowledge of:</p> <ul style="list-style-type: none"> <li>• numerical analysis and optimization,</li> <li>• understanding general principles of design optimization</li> <li>• formulating the optimization problems and identify critical elements.</li> </ul>                                                                                                                                                                                                                                              | <p>After completing this course students are able to successfully apply the acquired theoretical and practical knowledge and are able to:</p> <ul style="list-style-type: none"> <li>• Identify relevant optimization variables, define the set of functional constraints and limitations for the corresponding optimization model of a given mechanical system.</li> <li>• Apply linear and non-linear numerical methods for solving the optimization problems and define the appropriate convergence criteria.</li> <li>• Develop and implement computer programs in software packages Python / MATLAB for solving the set of optimization tasks.</li> <li>• Analyze the results and check the validity of the proposed optimization models with respect to the</li> </ul> |

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|     |                          |      |            |                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | change of input parameters.<br>•Apply the stochastic - heuristic methods and develop hybridized heuristic methods to determine the global solution of the optimization problems of complex mechanical systems.<br>•Develop new and apply existing numerical methods for solving complex optimization tasks, individually or as part of an appropriate team.                                                                                                                                                                                                        |
| 3.3 | information technologies | 1149 | obligatory | <b>Numerical Methods in Continuum Mechanics</b> | 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. | 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. |
| 3.4 | aerospace engineering    | 1474 | elective   | <b>Project Management &amp; Air Regulation</b>  | Course objective<br><br>• Understanding the importance of project management in aviation.<br>• The creation, introduction and use of aviation projects.<br>• Determining the functionality of your own projects.<br>• Preparation, analysis and project management.                                                                                                                                                                                                                                                                | The acquired knowledge enables the student to:<br>• Prepare, create and show their own skills,<br>• Determine the functionality of the aviation project,<br>• Prepare, perform and manage the development of the aviation project,<br>• Determine technology of designing an aviation project,<br>• Recognize the requirements of the local aviation industry in projects,                                                                                                                                                                                         |

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|     |                          |      |          |                                              | <ul style="list-style-type: none"> <li>• Understanding and preparing the necessary documents for the implementation of projects.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                             | <ul style="list-style-type: none"> <li>• Make the necessary documentation of aviation project,</li> <li>• Implement and collect aviation project.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 3.4 | information technologies | 1496 | elective | <b>Computer Graphics and Virtual Reality</b> | <p>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.</p> | <p>After successful completion of the program provided by this subject student can:</p> <ul style="list-style-type: none"> <li>• apply the acquired knowledge in the scientific, technical and engineering applications of virtual reality technology,</li> <li>• to design engineering software based on computer graphics,</li> <li>• to integrate knowledge in the field of video game physicality.</li> </ul>                                                                                                                                                                                                                                                                     |
| 3.4 | biomedical engineering   | 1344 | elective | <b>Information Technologies in Medicine</b>  | <p>Introducing students with fundamental principles of applied information technologies in medicine, with a goal of examining the important characteristics of implementations of new technologies in medicine. Simulation of realistic problems and specific requirements for implementation of logical structures in hospitals, telediagnosics, national and global healthcare information systems.</p>                                                                                                                               | <p>Upon successful completion of this course, students shall be able to:</p> <ul style="list-style-type: none"> <li>•Distinguish different branches of software engineering, as well as to differentiate which part of the Information System covers which branch of software engineering</li> <li>•Define the specifics of medical information systems and ways of their design</li> <li>•Apply the acquired knowledge to create models of simple and medium complexity of medical information systems</li> <li>•Adequately analyze the requirements for the creation of an information system for a given problem</li> <li>•Create a set of models that define a medical</li> </ul> |

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|     |                       |      |          |                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p>information system</p> <ul style="list-style-type: none"> <li>• Create the necessary documentation and models for the development-construction of medical information systems</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 3.4 | weapon systems        | 1562 | elective | <b>Hybrid technical systems</b> | <p>Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical requirements as part of a complex system or the system as a whole</li> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul> |
| 3.5 | aerospace engineering | 0645 | elective | <b>Aeroelasticity</b>           | <ol style="list-style-type: none"> <li>1. introduction to modern aeroelasticity problems and their analysis and practical methods to solving aeroelasticity problems in real aircraft structures</li> <li>2. introduction to experimental dynamic analysis of aircraft structures</li> <li>3. introduction to dynamics of thin walled structures</li> </ol>                                                                                                                                                                                        | <p>After successful completion of the course students should be able to:</p> <ol style="list-style-type: none"> <li>1. Determine forms of oscillation of thin walled structure</li> <li>2. calculate the torsional divergence speed of lifting surface</li> <li>3. Calculate the command reversal speed (aileron) on the wings</li> <li>4. Estimate flutter speed of the lifting surface using Teodorsen method</li> <li>5. Generate finite element models of lifting surfaces of the aircraft for static and dynamic aeroelastic</li> </ol>                                                                                                     |

analysis .

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| 3.5 | thermal power engineering | 1320 | elective   | <b>Computer simulations of thermalhydraulic processes and CFD</b> | 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.                                                                                                                                          | 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.                                                                                                                                                                                                                           |
| 3.5 | industrial engineering    | 1418 | elective   | <b>Appraisal of Projects in IT field</b>                          | Understanding the importance of the process of planning, evaluating and evaluating projects in the field of information technology. Introduction to different methodological approaches for the analysis of IT / IS projects. Mastering sophisticated techniques of financial and economic analysis as well as standard techniques for managing IT / IS projects. Mastering techniques and routines for identifying and monetary quantification of difficult to detect costs and effects implied by the implementation of IT / IS projects. | After completing the course the student should: identify the project idea, prepare a database with all costs and effects of IT / IS projects, calculate criteria for selection of project alternatives, gain knowledge and routines for recognizing difficult costs and effects of IT / IS projects, organize networks project resource flow activities with the choice of optimal paths and minimum costs and assess the uncertainty and risk of IT / IS projects. |
| 4.1 | information technologies  | 1497 | obligatory | <b>Skill Praxis M - MIT</b>                                       | 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                                                                                                                                                                                                                                                                                          | 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                                                                                                                                                                                                         |

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|     |   |      |            | well as roles and tasks of mechanical engineering of information technology in such business system.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | students to selected companies or institutions, way of doing business, management and the place and role of IT engineers in their organizational structures.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b><br>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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. | Upon the successful completion of M.Sc. Thesis Project, engineers should be able to: <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul> |

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| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> | <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |
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## Mechanics

| position | department | ID   |            | title                       | goal                                                                                                                                                                                                                                                                                                                       | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
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| 1.1      | mechanics  | 0825 | obligatory | <b>Analitical mechanics</b> | -To provide students knowledge of the fundamental principles and methods in Analytical Mechanics<br>-To enable students to solve practical problems in Analytical Mechanics using acquired knowledge in Analytical Mechanics<br>- to monitoring novelties in science and engineering                                       | -To enable students to master terms, methods and principles in Analytical Mechanics<br>-To enable students to relate the knowledge from knowledge in other scientific fields with knowledge Analytical Mechanics<br>-To apply knowledge from Analytical Mechanics in analysis, synthesis and prediction of solutions and consequences of problems in science<br>- To monitoring novelties in science and engineering                                                                                                                                 |
| 1.2      | mechanics  | 1315 | obligatory | <b>Continuum Mechanics</b>  | 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.                        | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• form Green (Lagrangian) strain tensor;</li> <li>• form Eulerian strain tensor;</li> <li>• form velocity strain tensor;</li> <li>• determine the stress tensor components;</li> <li>• compose general equation of motion (Navia) of any deformable medium;</li> <li>• form continuity equation (conservation of mass);</li> <li>• apply the theorem of the change in total energy of a continuous medium in integral form.</li> </ul> |
| 1.3      | mechanics  | 0004 | elective   | <b>Mechanics M</b>          | 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 | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> </ul>                                                                                                                             |

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|     |                 |      |          |                          | spherical and general rigid body motion, the approximate theory of gyroscope and the impact theory.                                                                                                                                                                                                            | <ul style="list-style-type: none"> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul>                                                                                                                                                                                                                             |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | 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. | 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. |
| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b>  | 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           | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> </ul>                                                                                                                                                                                                                                                                                       |

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.

- 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.

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>               | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements. | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution. |
| 1.5 | mathematics                       | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                                                                                         | Upon successful completion of this course, students should be able to:<br><br>1) Calculate probability and conditional probability of random events.                                                                                                                                                                                                 |

2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.

3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.

4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.

5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | hydropower engineering | 1423 | elective | <b>Pumps and fans</b>     | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function. | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density. |
| 1.5 | fluid mechanics        | 1558 | elective | <b>Transport of fluid</b> | The goal of studying the subject is to learn                                                                                                                                                                                                                                | As a result of studying the subject, mastering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                        |      |            | <b>through pipes</b>        | and study important engineering problems related to the pipeline transport of fluids, and especially to the calculation methods 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, methods of pipe support and techno-economic analysis of pipeline transport. | theoretical assumptions, physical laws, approximations and calculation methods of one-dimensional fluid flows through special purpose pipelines, such as: water pipelines, hot water pipelines, oil pipelines, gas pipelines and steam pipelines. As a result of the course, practical knowledge is obtained to solve technical problems: water hammer in pipelines, corrosion of pipelines, thermal expansion of pipelines and ways of supporting pipes.                                                                                                                                                                                                                                                                                                                                                    |
| 2.1 | strength of structures | 0903 | obligatory | <b>Theory of elasticity</b> | <p>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.</p> <p>Students will be enabled to model and solve some rheological problems. Through understanding the rheological processes, they will be able to use computer programs in this field.</p>          | <ul style="list-style-type: none"> <li>- By negotiation of this program, students will master some basic methods and procedures of the theory of elasticity and of the tensor method.</li> <li>- They will be able to calculate stress components on the base of the equilibrium equations and to form appropriate tensors of stress and strain for an ideal elastic body.</li> <li>- They will be introduced with principal stresses (intensity, position) and with maximum shear stress.</li> <li>- They will be able to calculate main strains.</li> <li>- Students will master application of material failure theories.</li> <li>- They will understand elasticity and stiffness matrixes.</li> <li>- They will be able to solve some real problems related to thin simply supported plates.</li> </ul> |
| 2.2 | fluid mechanics        | 0829 | obligatory | <b>Fluid Mechanics 1</b>    | 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                                                                                                                                                                         | <p>Students are trained to:</p> <ul style="list-style-type: none"> <li>- 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</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

process of finding the solution to specific engineering problems, and also improves his scientific and practical development.

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.

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| 2.3 | fluid mechanics | 0939 | obligatory | <b>Computational Fluid Mechanics</b> | 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 | <p>Upon successful completion of the course, students will be able to:</p> <ul style="list-style-type: none"> <li>- explain the general principles of numerical solution of governing equations for fluid flow</li> <li>- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow</li> <li>- explain and apply principles of numerical grid generation</li> <li>- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers</li> </ul> |
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|     |                             |      |          |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <p>equation)</p> <ul style="list-style-type: none"> <li>- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in various domains</li> <li>- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow</li> </ul>                                                                                                                                                                                                                                  |
| 2.4 | internal combustion engines | 1478 | elective | <b>Sensors and Computer Based Measurements</b>         | <p>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 to the world of virtual instrumentation and graphical programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in functioning and using DAQ systems through numerous, real-world examples. To get closer acquaintance with the sensors, and digital acquisition software &amp; hardware, in general, and methods of DACQ software development and testing.</p> | <p>Ability to integrate sensors and DAQ hardware in measurement chains in order to fulfill specific requirements in the field of mechanical engineering system testing &amp; measurements. Ability to build and test software applications (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 the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.</p> |
| 2.4 | hydropower engineering      | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | <p>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</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,</li> </ol>                                                                                                                                                                                                                                                                                                                                                                  |

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.

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.

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| 2.4 | mechanics | 0037 | elective | <b>Theory of Mechanical Vibrations</b> | <p>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.</p> | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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).</li> <li>•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).</li> <li>•Calculate (analytical and numerical) quantities which characterize vibration processes: natural frequencies, amplitudes, phase angles, logarithmic decrements and modal matrix.</li> </ul> |
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- 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.

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| 2.5 | strength of structures | 0721 | elective | <b>Basics of Composite Materials Mechanics</b> | <p>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.</p> | <ol style="list-style-type: none"> <li>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.</li> <li>2. Students will learn how to perform stress – strain analysis of laminate composite materials.</li> <li>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.</li> <li>4. By completing this course students will become</li> </ol> |
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|     |                     |      |            |                              |                                                                                                                                                                                                                                                                                                                                            | 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.                                                                                                                                                                                                                                                                                                                       |
| 2.5 | fluid mechanics     | 1011 | elective   | <b>Gas Dynamics</b>          | <p>The student should:</p> <ol style="list-style-type: none"> <li>1. acquire basic theoretical knowledge in the field of gas dynamics;</li> <li>2. be trained to perform basic engineering calculations of compressible flows;</li> <li>3. become familiar with the basic procedures for experimental research in gas dynamics.</li> </ol> | 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.                                                                                                                                                                                                                 |
| 2.5 | control engineering | 0599 | elective   | <b>Industrial Automation</b> | 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.                                                                                      | <p>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.</p> <p>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.</p> <p>Student is able to create HMI project with operators panel.</p> |
| 3.1 | mechanics           | 0827 | obligatory | <b>Mechatronic robotics</b>  | Introduce students to basic concepts of kinematics and dynamics of robotic systems. It is possible to solve direct and                                                                                                                                                                                                                     | <ul style="list-style-type: none"> <li>• Determine the type of kinematic chain and the number of degrees of freedom of given robotic system (RS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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.

- 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

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|     |                        |      |            |                                        | <ul style="list-style-type: none"> <li>• Compare the existing concepts of control mechanical systems and choose the appropriate concept of control for the considered RS.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 3.2 | fluid mechanics        | 1381 | obligatory | <b>Multiphase flow M</b>               | <p>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.</p> <p>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.</p> |
| 3.3 | strength of structures | 1133 | obligatory | <b>Theory of finite element method</b> | <p>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</p> <p>Upon completing the course students will be able to:</p> <ul style="list-style-type: none"> <li>-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;</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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.

-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.

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| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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. | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> </ul> |
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|     |                     |      |          |                                    | <ul style="list-style-type: none"> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 3.4 | control engineering | 0657 | elective | <b>Intelligent Control Systems</b> | <ul style="list-style-type: none"> <li>• Introduction to methods for the analysis and design of intelligent control systems.</li> <li>• Gaining practical knowledge of several of the main techniques of intelligent control and an introduction to some promising research directions.</li> <li>• Use of the computer for simulation and evaluation intelligent control systems.</li> </ul>                                                                                                                                                                                                                                                                                                                                  | <p>On successful completion of the course the students should be able to:</p> <ul style="list-style-type: none"> <li>• Understand of the functional operation of a variety of intelligent control techniques.</li> <li>• Understand of control-theoretic foundations.</li> <li>• 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.</li> <li>• Use of the computer for simulation and evaluation intelligent control systems through Matlab/Simulink software, as and practical realization of control algorithms on various control plants using programming software Matlab.</li> </ul> |
| 3.4 | weapon systems      | 1562 | elective | <b>Hybrid technical systems</b>    | Acquisition of general and basic knowledge about hybrid technical systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Upon successful completion of this course, students should be able to:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                 |      |          |                                       | <p>(HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning.</p> | <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical requirements as part of a complex system or the system as a whole</li> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                        |
| 3.5 | fluid mechanics | 0940 | elective | <b>Microfluidics and Nanofluidics</b> | <p>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.</p>                                                                                                                                                                             | <p>Students are trained to:</p> <ul style="list-style-type: none"> <li>-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;</li> <li>-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;</li> <li>- calculate the velocity and pressure field for isothermal compressible gas flow in micro channels, pipes and bearings for the slip flow regime;</li> <li>- calculate the velocity, pressure and temperature field for non-isothermal compressible gas flow in micro channels, for the slip flow regime;</li> <li>-calculate the pressure and velocity field for electroosmotic flow in micro and nano channels and pipes;</li> <li>- applie the law of diffusion equation and obtained</li> </ul> |

|     |                           |      |          |                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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|     |                           |      |          |                                                                    | <p>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;</p> <p>-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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 3.5 | production engineering    | 1537 | elective | <b>Computer control and monitoring in manufacturing automation</b> | <p>The goal of the course is for students to acquire the necessary knowledge in the application, design, and implementation of modern computer control and monitoring systems in manufacturing automation, as well as to get skills for solving practical problems of computer control and monitoring in automation.</p> <p>After completing this course the students should be able to: 1. Apply a stepper motor to actuate a mechanical system within the manufacturing process, including designing the hardware architecture and control system based on integrated microcontrollers; 2. Implement a system for moving two or more controlled axes using interpolation algorithms based on the direct search method; 3. Physically realize the task of multi-axis movement defined in G-code on a microcontroller platform with interpolation algorithms based on direct search methods; 4. Generate a program for the movement of anthropomorphic robots and achieve their integration with the sensor environment by including real-time signal processing; 5. Conceptualize a system for computer monitoring of the manufacturing process.</p> |
| 3.5 | thermal power engineering | 1320 | elective | <b>Computer simulations of thermalhydraulic processes and CFD</b>  | <p>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</p> <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

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|     |           |      |            |                               | two-phase systems in pipelines and plant equipment, including the methods of Computational Fluid Dynamics - CFD.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 4.1 | mechanics | 1202 | obligatory | <b>Skill Praxis M - MEH</b>   | 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.                                                                                                                                                                                                                                                                                                                                    | 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.                                                                                                                                                                                                                                                                                                                                                 |
| 4.3 | -         | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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. | <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> </ul> |

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|     |   |      |            |                     | <ul style="list-style-type: none"> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                           |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Motor Vehicles

| position | department     | ID   |            | title                       | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| 1.1      | motor vehicles | 1333 | obligatory | <b>Vehicle design</b>       | 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. | 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.                                                                                                                                                                                                                   |
| 1.2      | motor vehicles | 0711 | obligatory | <b>System Effectiveness</b> | 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).                                                                                                                                                                                                                                                                                                                                   | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>- Explain the concepts of system effectiveness, reliability and failure;</li> <li>- Analyze the obtained failure time data;</li> <li>- Apply of the basic laws of probability and statistics to calculate the reliability;</li> <li>- Obtain theoretical probability density and reliability function based on empirical data on failures of the elements;</li> <li>- Determine the reliability of a complex system based on the reliability of the elements that form a complex system;</li> <li>- To form fault tree of technical system and analyze it;</li> </ul> |

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|     |                 |      |          |                          |                                                                                                                                                                                                                                                                                                                                                                                                                                       | - To design machine elements on the basis of reliability.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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:</p>                                                                                                                                                                                                                |

|     |                                   |      |          |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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|     |                                   |      |          |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | incompressible and compressible flow in pipes and nozzles.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.<br>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.                                                                                                                                                                              | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• Recognize and determine the thermodynamic</li> </ul> |

properties of wet gases and implement them in the analysis of thermomechanical processes in devices and facilities with moist air.

|     |                |      |          |                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
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| 1.5 | motor vehicles | 1141 | elective | <b>Maintenance of Machinery and Equipment</b> | <p>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.</p> <p>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:</p> <p>International standard for Asset Management with focus on:</p> <ul style="list-style-type: none"> <li>- What is Asset management and why it is important to an organization</li> <li>- The benefits of a management system for asset management</li> <li>- The key terms, concepts and principles of ISO 55001:2014</li> <li>- The main requirements of ISO 55001:2014</li> </ul> | <p>Upon this comprehensive one semester course, students will be able to:</p> <ul style="list-style-type: none"> <li>- Recognize and be able to apply asset management terminology, definitions and principles</li> <li>- Identify and manage the expectations of stakeholders with respect to asset management</li> <li>- Become familiar with internationally recognized asset management methodologies and good practices</li> <li>- Apply structured approaches available for the improvement of value realization from assets</li> <li>- Recognize the value obtainable from the integrated approach to the life cycle and risk-based management of assets</li> <li>- Understand what Maintenance is doing</li> <li>- How maintenance should be measured</li> <li>- What maintenance is achieving for the business and</li> <li>- What more it can do to improve operational performance</li> <li>- Ensure that projects are set-up for success from the start</li> <li>- Understand the role of the project manager, business analyst, and others in managing projects</li> <li>- Develop an integrated project plan including realistic scope, schedules, budgets, and risks</li> <li>- Learn how to effectively track and report on</li> </ul> |
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- Maintenance KPI Key Performance Indicators

project progress

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

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| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b> | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines. | Upon successful completion of this course, students should be able to:<br>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;<br>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;<br>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;<br>4) recognize on the basis of the acquired knowledge |
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the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.  
 Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.  
 Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

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| 1.5 | mathematics | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling. | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> <li>2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.</li> <li>3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.</li> <li>4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.</li> <li>5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.</li> <li>6) Apply learned technique of probability</li> </ol> |
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|     |                |      |            |                                                  |                                                                                                                                                                                                                                                                                                                                              | calculation for modeling work of the technical system by Monte Carlo method.                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2.1 | motor vehicles | 1334 | obligatory | <b>Vehicle Propulsion and Suspension Systems</b> | 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.                                                                               | 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. |
| 2.2 | motor vehicles | 0872 | obligatory | <b>Automotive friction systems</b>               | 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.                                                                                        | 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.                                                                  |
| 2.3 | motor vehicles | 0873 | obligatory | <b>Vehicle Mechatronics</b>                      | 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. | Upon successful completion of this course, students should be able to:<br>- explain the concept of mechatronics and mechatronic systems, with respect to vehicles;<br>- describe in a nutshell the function of all components of vehicle mechatronic systems;<br>- analyse and explain the specificities of vehicle mechatronic systems (suspension systems, braking systems, power transmission systems, steering                                                                                                                    |

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|     |                                    |      |          |                                        |                                                                                                                                                                                                                                                                                                                                                                                                                           | <p>systems, integrated systems);</p> <ul style="list-style-type: none"> <li>- analyze the problems when designing a vehicle mechatronic system;</li> <li>- 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);</li> <li>- simulate the operation of the designed mechatronic system, as well as to define the testing method for the system in question.</li> </ul>      |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>                     | <p>Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.</p> | <p>Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.</p>                                                                           |
| 2.4 | mechanics                          | 0037 | elective | <b>Theory of Mechanical Vibrations</b> | <p>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.</p>                                                                                                                                                                                               | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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</li> </ul> |

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.

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| 2.4 | motor vehicles | 0451 | elective | <b>Systems Engineering</b> | Course objectives include the achievement of competencies and academic skills as well as methods for their acquisition, in the field of engineering systems. The goals arising from basic tasks and determine the specific results that should be realized within the subject and represent the basis for the control of the results achieved. | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Follow and evaluate functional effectiveness of different systems;</li> <li>- Determine methodology for evaluation of system working during their life cycle;</li> <li>- Explain term-system work quality: production and/or service;</li> <li>- Apply different methods and techniques for risk</li> </ul> |
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|     |                        |      |          |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <p>and project management;</p> <ul style="list-style-type: none"> <li>- Manage costs of life cycle systems;</li> <li>- Explain demands of different series of international standards and ways of their using in different types of organizations;</li> <li>- Connect engineer and manager demands in work processes of different types of organizations;</li> <li>- Adopt and evaluate decisions in conditions of certainty and uncertainty which occurs during system working;</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                        |
| 2.5 | motor vehicles         | 0874 | elective | <b>Vehicles and Environment</b>             | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>- Explain the concept of fuel consumption and the possibilities for its reduction;</li> <li>- Analyze the impacts of driver on fuel consumption;</li> <li>- 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;</li> <li>- Identify alternative vehicle drives and fuels;</li> <li>- Analyze working principles of hybrid and electric vehicles;</li> <li>- Explain the impact of noise and vibration produced by vehicle;</li> <li>- Recognize environmentally friendly and modern materials used in the design and manufacture of vehicles;</li> <li>- Describe the recycling process and the life cycle of the vehicle.</li> </ul> |
| 2.5 | production engineering | 0722 | elective | <b>Computer Simulation in Manufacturing</b> | <p>The objective of this course is that students: acquire knowledge and skills necessary for practical problems solving in</p>                                                                                                                                                                                                                                                                                                                             | <p>After successfully completing this course, the students should be capable to:</p> <ul style="list-style-type: none"> <li>- Create and implement stochastic simulation;</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|     |                     |      |            | <b>Automation</b>             | <p>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.</p> | <ul style="list-style-type: none"> <li>- Create conceptual model for discrete event simulation;</li> <li>- Create and implement discrete event simulation within fixed and flexible automation framework;</li> <li>- Create conceptual and computer model for continuous simulation of various processes;</li> <li>- Integrate continuous and discrete event simulation;</li> <li>- Manage discrete event simulation project.</li> </ul>                                                                                                                                                                   |
| 2.5 | control engineering | 0599 | elective   | <b>Industrial Automation</b>  | <p>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.</p>                                                                                                                                                                                                               | <p>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.</p> <p>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.</p> <p>Student is able to create HMI project with operators panel.</p> |
| 3.1 | motor vehicles      | 0441 | obligatory | <b>Vehicle body structure</b> | <p>Aims of this course include achieving the competences to conquer specific knowledge and skills needed for overviewing and understanding problems related to construction, calculation,</p>                                                                                                                                                                                                                                                                              | <p>After successful completion of this course, students should be trained to:</p> <ul style="list-style-type: none"> <li>- Know and explain basic methods and procedures for vehicle's body behaviour identification;</li> <li>- List and explain characteristic calculation regimes</li> </ul>                                                                                                                                                                                                                                                                                                            |

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|     |                |      |            |                            | testing and verification of support structures of different categories of vehicles.                                                                                                                                                                                                                                                                                                            | <p>specificities in body calculation;</p> <ul style="list-style-type: none"> <li>- Recognize and explain the problems of thin-walled open cross-sections;</li> <li>- Identify and interpret basic postulates of UN Regulations regarding the strength of bus superstructures;</li> <li>- Analyze and explain basic problems of strength related to chassis – body interaction;</li> <li>- Categorize different body types regarding their torsion stiffness and propose the application of appropriate elements for connection;</li> <li>- Define all aspects needed for completion of commercial vehicles, taking into account related bodybuilder instructions.</li> </ul> |
| 3.2 | motor vehicles | 1143 | obligatory | <b>Vehicle Testing</b>     | 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.                                                                                                                    | 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.                                                                                                                                                                                                                                                                                                             |
| 3.3 | motor vehicles | 0875 | obligatory | <b>Vehicle Maintenance</b> | 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 | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>-Explain the processes of technical maintenance of different motor vehicle types and categories;</li> <li>-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;</li> <li>-Organize and implement different concepts and</li> </ul>                                                                                                                        |

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.

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.);

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| 3.4 | engineering materials and welding, tribology, fuels and combustion | 0519 | elective | <b>Tribology</b> | <p>The student attending this course should:</p> <ul style="list-style-type: none"><li>• 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;</li><li>• 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;</li><li>• Solve problems related to the prevention of wear and competently decide on techniques to improve</li></ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"><li>• Identifies and critically analyze the basic causes of energy and material dissipation in some mechanical system;</li><li>• Recognize the dominant type of wear in some mechanical system and to propose appropriate measures for its reduction;</li><li>• Choose the appropriate type of material for the basic tribological elements (plain bearings, roller bearings and gears);</li><li>• Describes and distinguishes the most common surface modification and coating deposition methods;</li></ul> |
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|     |                |      |          |                                    | tribological properties of materials and lubrication technologies.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <ul style="list-style-type: none"> <li>• Explain the influences of temperature and pressure on the value of the viscosity (lubricants rheology);</li> <li>• Describes and distinguishes the basic types and methods of lubrication with their characteristics.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                            |
| 3.4 | motor vehicles | 0713 | elective | <b>Intelligent vehicle systems</b> | <p>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</p> | <p>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.</p> |

of intelligent vehicle systems development.

|     |                                               |      |          |                                                                  |                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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| 3.4 | material handling, construction and logistics | 1542 | elective | <b>Fundamentals of Mining and Construction Machines Dynamics</b> | 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.                 | By successfully completing this course the student should acquire the following competences:<br><ul style="list-style-type: none"> <li>• Properly forming the reduced dynamic models of earthmoving machines such as single-bucket excavators and bulldozers;</li> <li>• 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;</li> <li>• 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;</li> <li>• Creating dynamic models of continuous excavators' substructures;</li> <li>• Identification and analysis of continuous excavators' substructures response to excitation caused by resistance to excavation;</li> <li>• Calculation and proper selection of basic parameters of conveyor belts with relatively high conveyor speed, dominantly used in mobile continuous earthmoving machines.</li> </ul> |
| 3.5 | motor vehicles                                | 0876 | elective | <b>Forensic Engineering</b>                                      | Student is enabled to apply forensic engineering methods, particularly in the area of motor vehicles, which comprises analyses and reconstruction of road accidents. Analogous methods will be applied in other fields of mechanical engineering, depending on the interest of | Upon successful completion of this course, students should be able to:<br><ul style="list-style-type: none"> <li>- explain the concept of forensics and forensic engineering, with respect to vehicles;</li> <li>- define and analyze technical system failures, their causes and effects, with a special emphasis on the application in automotive field;</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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|     |                        |      |          |                       | students.                                                                                                                                                                                                                                                                   | <ul style="list-style-type: none"> <li>- identify and analyze the causes of traffic accidents in which vehicles participated, with elements of investigation and reconstruction;</li> <li>- analyze adequate technical solutions and conditions under which accidents might be avoided.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                   |
| 3.5 | thermomechanics        | 0924 | elective | <b>Solar energy</b>   | Achieving academic competences in the field of solar energy utilization. Acquiring theoretical and practical knowledge on converting solar into thermal energy, acquiring skill of modeling and simulation of processes.                                                    | <p>Upon successful completion of this course students should be able to:</p> <ul style="list-style-type: none"> <li>• Explain the characteristics of solar radiation at a specific location;</li> <li>• Analyze energy transport in the elements of the solar thermal systems;</li> <li>• Formulate the mass and energy balances for the elements of the solar system (for solar collectors, thermal energy storages, heat exchangers, pipelines);</li> <li>• Determine representative energetic characteristics of appropriate elements of the system;</li> <li>• Analyze and thermodynamically evaluate the operation of various solar thermal systems.</li> </ul> |
| 3.5 | hydropower engineering | 1423 | elective | <b>Pumps and fans</b> | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function. | <p>Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the</p>                                                                                                                                                    |

|     |                |      |            |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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|     |                |      |            |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 4.1 | motor vehicles | 1224 | obligatory | <b>Skill Praxis M - MOV</b>   | 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.                                                                                                                                                                                                                                                                                                                                                                               | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 4.3 | -              | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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. | <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the</li> </ul> |

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|     |   |      |            |                     | ability of lifelong learning;<br>• Consider different solutions critically and self-critically;<br>• Apply the acquired knowledge in practice;<br>• Adapt to newly arising situations in practice.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Naval Architecture

| position | department    | ID   |            | title                  | goal                                                                                                                                                                                                                                                                                                                                                                                                                                      | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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| 1.1      | naval systems | 0955 | obligatory | <b>Ship resistance</b> | <p>Within the course, students are introduced to the fundamentals of marine hydrodynamics and how the basic parameters of a ship's hull form influence ship resistance. They are trained to determine ship resistance for common types of seagoing ships by applying traditional engineering methods. Additionally, the course explores other conventional and unconventional types of ships from the perspective of ship resistance.</p> | <ol style="list-style-type: none"> <li>1. The student is thoroughly acquainted with the basic physical phenomena that characterize a ship's navigation. In this context, traditional, but also contemporary methods for solving complex physical phenomena, in order to determine a ship's calm water resistance, are considered. Special attention is given to conducting model-scale experiments and procedures involved in extrapolating and applying these findings to a full-scale ship.</li> <li>2. The student is capable of applying comprehensive knowledge of mathematics, fluid mechanics, and basic engineering principles to determine the resistance of a ship during navigation.</li> <li>3. The student demonstrates the ability to conduct a comprehensive analysis of the primary and secondary characteristics of a typical sea-going ship's hull form. The purpose of this analysis is to optimize the hull form, with respect to ship resistance.</li> <li>4. The student can assess the impact of selected ship design parameters on ship resistance to mitigate adverse environmental impacts.</li> <li>5. The student is qualified to choose and apply appropriate empirical and numerical methods to determine ship resistance, considering both the limitations of the waterway and the methods applied.</li> </ol> |

6. The student can select and critically evaluate relevant technical literature and other sources of information to address complex problems in the field of ship hydrodynamics, with a particular focus on determining ship resistance.

7. The acquired knowledge enables the student to address complex engineering challenges and meet specific design requirements imposed by contemporary trends in naval architecture, particularly those related to ship resistance.

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| 1.2 | naval systems | 1015 | obligatory | <b>Ship strength 1</b> | <p>The course aims to prepare students with a comprehensive understanding, selection of appropriate methods for solving, and the direct resolution of fundamental ship strength problems. These include: basic modes of hull failure and limit states, hull responses, bending of stiffeners with and without attached plating, effective width of plating, geometrically similar sections, buckling of stiffeners, response of ship's transverse sections (frames), bending of plates (platings), buckling of unstiffened and stiffened plates (platings), effective width of plates.</p> | <p>1. Students will be able to apply comprehensive knowledge from fundamental natural and technical sciences (mainly: strength of materials, strength of structures, mechanical materials, mechanics) and engineering principles to solve fundamental ship strength problems such as: basic modes of hull failure and limit states, hull responses, bending of stiffeners with and without attached plating, effective width of plating, geometrically similar sections, buckling of stiffeners, response of ship's transverse sections (frames), bending of plates (platings), buckling of unstiffened and stiffened plates (platings), and effective width of plates.</p> <p>2. Students will be capable of formulating and setting fundamental ship strength problems (abovementioned), using the foundations of natural sciences and engineering principles, to reach relevant conclusions while considering the limitations of methods and data incompleteness.</p> <p>3. Students will be able to select and apply analytical and computational methods to model the fundamental ship strength problems (abovementioned), while considering the</p> |
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limitations of these methods.

4. Students will be capable of independently finding and critically using technical regulations (rules and regulations of classification societies and national registries, as well as other regulatory bodies), literature (papers, studies), and other information sources (data from shipowners, design offices, shipyards, estimated data, etc.) to solve the fundamental ship strength problems (abovementioned).

5. Students will be able to select and apply materials, consider shipbuilding technologies and processes, as well as their limits.

6. Students will be able to communicate complex engineering issues related to ship strength to both technical and non-technical audiences, evaluating the effectiveness of the methods used. This will be achieved by assigning ship strength topics for students to research and then present.

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| 1.3 | mechanics | 0004 | elective | <b>Mechanics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"><li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li><li>• Analyze the motion of variable mass particle.</li><li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li><li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li><li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and</li></ul> |
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|     |                 |      |          |                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | cases of approximate theory of gyroscopic phenomena using Reza theorem.<br>• Solve problems related to the impact (collision) of a particle and rigid body.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | 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.                                                                                                                                                                                | 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. |
| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b>  | 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 | Upon successful completion of this course, students should be able to:<br>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.<br>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.<br>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.<br>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic                                                                                                                      |

conditioning of corresponding spaces.

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.

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>               | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements. | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                           |
| 1.5 | mathematics                       | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                                                                                         | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> <li>2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.</li> <li>3) Determine distribution functions, density</li> </ol> |

functions, characteristic functions, expected value and variance of continuous random variables.

4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.

5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | internal combustion engines | 1435 | elective | <b>Internal Combustion Engines Fundamentals</b> | The course provides a comprehensive insight into the matter of teh internal combustion (IC) engines (theoretical cycles, actual process, engine systems, operating characteristics). It is intended for students at the Department for IC engines, as an introduction to a deeper study of specific areas of internal combustion engines, as well as students of those fields where knowledge of IC engines as a propulsion unit (motor vehicles, shipbuilding, railway engineering, mechanization) is necessary. | Adopted theoretical and practical knowledge in the field of engines. Connecting fundamental disciplines: thermodynamics, fluid mechanics, mechanics, material resistance, etc. on a complex object such as the internal combustion engine. Acquiring the skills for a competent approach in the selection, organization of operation and maintenance of engines. Acquiring a base for further study of specific problems, construction and design of engines. |
| 1.5 | naval systems               | 1459 | elective | <b>Ship structures 1M</b>                       | The course aims to equip students with the understanding and ability to design ship structures using the rules and regulations of classification societies. Additionally, it seeks to thoroughly                                                                                                                                                                                                                                                                                                                  | 1. Students will be capable of applying knowledge from fundamental natural, technical sciences (primarily: strength of materials, strength of structures, engineering materials) and engineering principles to the scantling determination and                                                                                                                                                                                                                |

acquaint students with all elements of ship structures and their roles within the ship's hull.

- optimization of ship structural elements.
2. Students will be able to formulate the roles of ship structural elements within the hull, by optimizing and designing them, based on the principles of natural sciences and engineering, considering method limitations and data incompleteness.
  3. Students will select and apply analytical and computational methods to model ship structural elements through their scantling determinations and optimization.
  4. Students will independently find and critically use technical regulations (rules and regulations of classification societies and national registries, among other regulatory bodies), literature (papers, studies), and other information sources (data from shipowners, design offices, shipyards, estimated data, etc.) for the scantling determination and optimization of ship structural elements.
  5. Students will apply a systematic approach to solving complex problems in the scantling determination and optimization of ship structures.
  6. Students will choose and apply appropriate materials, consider shipbuilding technologies and processes, and their limitations.

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| 2.1 | naval systems | 0956 | obligatory | <b>Ship propulsion</b> | <p>Within the course, students are introduced to the fundamentals of ship propulsion. Special attention is paid to the physical phenomena that characterize the operation of propellers. The study focuses on the complex conditions under which propellers operate, specifically examining propeller-ship interaction and the</p> | <p>1. The student has developed a thorough understanding of the fundamental physical principles that underlie ship propulsion. Within this framework, both traditional and contemporary methodologies for addressing complex physical phenomena are explored, to determine the optimal characteristics of a propulsion system in alignment with design requirements. The student is</p> |
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influence of propeller geometry and ship stern form on hydrodynamic performance. Students are trained to independently determine the optimal propeller characteristics using common engineering methods while considering specific requirements and determining the necessary specifications of the main engine for propelling a typical seagoing cargo ship. Besides, students are introduced to a range of modern technical solutions aimed at enhancing the efficiency of a ship's propulsion system, as well as various regulations concerning technical and environmental requirements related to ship propulsion.

acquainted with the model-scale experiments on propeller performance, as well as the procedures required to extrapolate and apply these findings to full-scale propellers.

2. The student adeptly applies a comprehensive understanding of mathematics, fluid mechanics, and fundamental engineering principles to assess the hydrodynamic performance of a propeller.

3. The student demonstrates the ability to critically analyze the impacts of both the basic geometric and hydrodynamic characteristics of propellers, taking into consideration the complex water inflow, particularly influenced by the stern design of typical seagoing vessels. This analysis aims to optimize ship propulsion.

4. The student can evaluate specific propeller characteristics to enhance the energy efficiency of the ship's propulsion system, leading to greater operational economy and minimized environmental impact.

5. The student is qualified to choose and apply appropriate empirical and numerical methods to determine the hydrodynamic characteristics of optimal propeller and required propulsive power while considering the design requirements and limitations of the methods employed.

6. The student can select and critically evaluate relevant technical literature and other sources of information to address complex problems in the field of ship hydrodynamics, with a particular focus on determining ship propulsion performances.

7. The acquired knowledge enables the student to address complex engineering challenges and meet

specific design requirements imposed by contemporary trends in naval architecture, particularly those related to ship propulsion.

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| 2.2 | naval systems | 1430 | obligatory | <b>Ship buoyancy and stability 2</b> | <p>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 Ship buoyancy and stability 1.</p> | <p>1. The student will be able to apply comprehensive knowledge from fundamental natural and technical sciences to solve ship stability problems during loading/unloading, flooding, and grounding. Additionally, the student will be familiar with regulations on ship damage stability, understand their origin and development, and their relation to accidents. The student will be aware of examples of good engineering practice within the subject topics and the directions of future development in this field;</p> <p>2. The student will be capable of formulating problems and analysing the impacts of loading/unloading, flooding, and grounding to reach well-founded conclusions about ship residual stability. This will include the analysis and qualitative assessment of available data during calculations, and using engineering judgement in cases of incomplete or unreliable information;</p> <p>3. The student will be able to select and apply appropriate computational and analytical techniques to model ship stability problems during loading/unloading, flooding, and grounding, considering the limitations of the applied techniques;</p> <p>4. The student will be able to communicate effectively on complex engineering matters of the course subject with technical and non-technical audiences, evaluating the effectiveness of the methods used.</p> |
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| 2.3 | naval systems | 1477 | obligatory | <b>Ship structures 2</b> | <p>The objective of the course is to enable students to understand and create projects related to the longitudinal strength of ships. Additionally, students should be equipped to understand and analyze the problem of a ship's ultimate strength. Students need to understand, identify differences and requirements, as well as to be capable of designing the structure of various types of ships (general cargo ships, container ships, bulk carriers, and others).</p> | <ol style="list-style-type: none"> <li>1. Students will be capable of applying comprehensive knowledge from fundamental natural, technical sciences (notably: strength of materials, strength of structures, engineering materials) and engineering principles to solving and analyzing global ship strength problems (longitudinal, ultimate, structural).</li> <li>2. Students will be capable, based on the use of fundamentals of natural sciences and engineering principles, to formulate and set fundamental problems of global ship strength (longitudinal, ultimate, structural), to reach relevant conclusions, keeping in mind the limitations of the methods and the incompleteness of data.</li> <li>3. Students will be able to select and apply analytical and computational methods to model fundamental problems of global ship strength (longitudinal, ultimate), considering the limitations of these methods.</li> <li>4. Students will be capable of independently finding and critically using technical regulations (rules and regulations of classification societies and national registers, as well as other regulatory bodies), literature (papers, studies), and other sources of information (data obtained from shipowners, design offices, shipyards, estimated data, etc.) to solve fundamental problems of global ship strength (longitudinal, ultimate, structural).</li> <li>5. Students will know how to apply a systematic approach in solving complex problems of global ship strength and ship structures.</li> <li>6. Students will know how to select and apply appropriate materials, consider shipbuilding</li> </ol> |
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|     |                        |      |          |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | technologies and processes, and their limitations.<br>7. Students will be capable of communicating complex engineering issues in the context of global ship strength (longitudinal, ultimate, structural) with both technical and non-technical audiences, evaluating the effectiveness of the methods used.                                                                                                                                                                                                                                                                                 |
| 2.4 | hydropower engineering | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | 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. | On successful completion of this course, students should be able to:<br>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,<br>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,<br>3. Process and present the measurement results,<br>4. Calculate the measurement uncertainty,<br>5. Explain the calibration of velocity, pressure and flow measuring devices,<br>6. Describe the types and characteristics of sensors. |
| 2.4 | mechanics              | 0037 | elective | <b>Theory of Mechanical Vibrations</b>                 | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                            | Upon successful completion of this course, students will be able to:<br><br>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.<br>•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.

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| 2.4 | naval systems | 0975 | elective | <b>Ship Equipment<br/>M</b> | Within the course, students are introduced to the basic characteristics of the most common types of marine displacement ships. Significant emphasis is placed on ship equipment, covering both mandatory components applicable to every vessel and the specific | <ol style="list-style-type: none"> <li>1. The student possesses in-depth knowledge of the fundamental features of typical displacement cargo ships, with a specific focus on ship equipment.</li> <li>2. The student is able to apply comprehensive knowledge in the fundamental natural and technical sciences, as well as engineering principles to solving problems related to complex technical</li> </ol> |
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equipment required for certain ship types. Within this course, we explore the details of individual ship equipment elements, including their purpose, technical characteristics, operational principles, and the procedures for selecting appropriate equipment and determining its placement during the design phase. In addition, students are introduced to the regulations of various elements of ship equipment.

requirements in determining characteristics and deployment on board individual elements of required ship's equipment.

3. Depending on the type and purpose of the ship, the student is capable of formulating requirements for necessary equipment during the design process, considering relevant regulations, and critically analyzing available options. This includes critically considering various available technical solutions, guided by engineering judgment, taking into account the purpose of the equipment, the specifics of ship construction, and the available space.

4. The student is capable of selecting and applying appropriate computational methods to determine the basic characteristics of required ship equipment.

5. The student is qualified to select relevant technical literature and other sources of information when determining the basic technical characteristics of necessary equipment during ship design.

6. The student is capable of designing, selecting, and arranging the necessary equipment on the ship, considering both the functionality of the equipment and the safety of the crew during equipment handling. The arrangement of equipment affects accessibility and directly influences efficiency: cargo handling, anchoring, mooring, deployment of life-saving equipment, etc.

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| 2.4 | naval systems | 1016 | elective | <b>Ship systems M</b> | To cover the basic knowledge of Marine Engineering connected to ship piping and pumping systems, to become familiar with ship systems (bilge, ballast, sanitary, |
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The outcome of the course is to familiarize students with ship systems and the basics of their calculation and design. Students will be capable of applying comprehensive knowledge from mathematics,

tanker systems, fire-fighting systems, etc.) and learn the basics of their calculation and design.

statistics, fluid mechanics, natural sciences, and engineering principles to solve complex problems, with a critical awareness of engineering development and broader context. They will also be able to formulate and analyze complex problems, assessing available data and using engineering reasoning to work with uncertain or incomplete information, considering the constraints of applied techniques. Moreover, students will know how to select and apply appropriate computer and analytical techniques for modeling complex problems, as well as choose and apply suitable materials, equipment, engineering technologies, and processes, respecting their limitations.

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| 2.5 | naval systems | 1017 | elective | <b>Ship strength 2</b> | <p>The objective of the course is to enable students to have a basic understanding of the theory of the finite element method, a comprehensive understanding of the engineering approach and the concept of using this method in shipbuilding, as well as to equip them for solving basic ship strength problems at the level of stiffeners, stiffened plates, frames, unstiffened plates, stiffened plates, or any other local part of the structure.</p> | <ol style="list-style-type: none"> <li>1. Students will be capable of applying knowledge from fundamental natural sciences and technical disciplines (notably: strength of material, strength of structures, materials, mechanics) and engineering principles in understanding the finite element method in shipbuilding, as well as in understanding and solving specific ship strength problems using this method, such as responses of: stiffeners, stiffened plates, frames, unstiffened plates, stiffened plates, or any other local part of the structure.</li> <li>2. Students will be able to, based on the use of fundamentals of natural sciences and engineering principles, formulate and pose fundamental problems (as mentioned above) in the analysis of ship strength using the finite element method to produce conclusions, while taking into account the limitations of the method and the incompleteness of data.</li> </ol> |
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3. Students will be capable of selecting and applying computational methods based on the finite element method to model fundamental ship strength problems (as mentioned above), bearing in mind the method's limitations. Additionally, students will compare those results with existing analytical solutions.
4. Students will be capable of independently finding and critically using technical regulations (rules and regulations of classification societies and national registers, as well as other regulatory bodies for analysis using the finite element method), literature (papers, studies), and other information sources (data obtained from shipowners, design offices, shipyards, estimated data, etc.) to solve fundamental ship strength problems (as mentioned above) using the finite element method.
5. Students will be able to apply a systematic approach to solving complex structural problems of ship strength using the finite element method.
6. Students will know how to select and apply appropriate materials, consider shipbuilding technologies and processes, and their limitations, in the analysis of structures using finite elements.

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| 2.5 | strength of structures | 0721 | elective | <b>Basics of Composite Materials Mechanics</b> | 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 |
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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

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.

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.

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| 2.5 | control engineering | 0599 | elective | <b>Industrial Automation</b> | 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. | <p>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.</p> <p>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.</p> <p>Student is able to create HMI project with operators panel.</p> |
| 2.5 | engineering         | 0720 | elective | <b>Quality</b>               | The aim of this course is for students to                                                                                                                                                                                                             | After fulfilling all the course requirements, as                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

materials and welding, tribology, fuels and combustion

**assurance and quality control of welded joints**

become competent in the area of quality assurance and quality control of welded joints and welded structures. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing.

prescribed by the course plan, the student is capable of applying the acquired knowledge to:

- Explain the importance of quality assurance (QA) and quality management (QM) of welded structures.
- Describes and to distinguish between different types of welded joint defects/imperfections/cracks.
- Defines possible causes for certain types of welded joint defects/imperfection/cracks.
- Defines the quality control plan for welding joints and welded structures.
- Apply quality control plan, QA and QM in the case of different welded structures.
- Defines specification and qualification of welding procedures for metallic materials.
- Connect the acquired knowledge in this field with other areas and applies them in practice.

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| 3.1 | naval systems | 1018 | obligatory | <b>Ship design</b> | <p>Ship Design is a course that integrates all the knowledge of naval architecture and shipbuilding that a student has acquired during their studies. The goal is for the student, through classes and an independent project, to master the basic knowledge and skills of ship design and international regulations in shipbuilding, including their origin, development, and particularly their impact on ship design. The course also includes a critical analysis of existing regulations and methods applied in ship design.</p> | <p>Through classes and an independent project, student will master basic knowledge and skills of ship design and international regulations in shipbuilding, becoming familiar with their development and impact on safety, environment, and design process. They will be capable of applying comprehensive knowledge of mathematics, statistics, natural sciences, and engineering principles to solve complex problems, with a critical awareness of the broader engineering context. The student will be able to formulate and analyze complex problems, assess available data, and use engineering reasoning to work with uncertain or incomplete information, know how to select and apply appropriate computational and analytical</p> |
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techniques for modeling complex problems, considering limitations of applied techniques and recommendations. The student will be able to critically evaluate technical literature and other sources of information to solve complex problems, to design solutions for complex problems that demonstrate originality and meet social, user, business, and client requirements, considering health, safety, diversity, inclusion, cultural, social, environmental, and commercial issues. The student will apply an integrated or systemic approach to solving complex problems, will be able to evaluate the impact of solutions to complex problems on the environment and society and minimize their negative impacts. The student will identify and analyze ethical issues and make reasonable ethical choices based on professional codes of conduct. They will be able to select and apply appropriate materials, equipment, engineering technologies, and processes, considering their limitations. The student will effectively function as an individual, a member or leader of a team, and will evaluate the effectiveness of their own and team performance. They will be able to effectively communicate complex engineering issues to technical and non-technical audiences, assessing the effectiveness of the methods used.

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| 3.2 | naval systems | 1431 | obligatory | <b>Seakeeping</b> | To cover the basic knowledge of Naval Architecture connected to ship motion in waves. | 1. The student will be able to apply comprehensive knowledge from fundamental natural and technical sciences to solve problems related to ship behaviour on waves – rolling, pitching, and heaving on regular and irregular waves. Additionally, the student will be familiar with the development of |
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wave theory and seakeeping analysis, and their significance and application to modern ship stability regulations;

2. The student will be capable of formulating problems related to seakeeping and analysing the impacts of changes in various parameters, such as changes in metacentric height, hull form, and the distribution and shifting of cargo on the ship. This will include the analysis and qualitative assessment of available data during calculations, and using engineering judgement in cases of incomplete or unreliable information;

3. The student will be able to select and apply appropriate computational and analytical techniques to model problems related to seakeeping, considering the limitations of the applied techniques;

4. The student will be able to communicate effectively on complex engineering matters of the course subject with technical and non-technical audiences, evaluating the effectiveness of the methods used.

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| 3.3 | internal combustion engines | 1025 | obligatory | <b>Marine Engines</b> | <p>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</p> | <p>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.</p> |
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|     |                        |      |            |                                                                                        | during professional practical work experience.                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 3.3 | industrial engineering | 1543 | obligatory | <b>Application of methods and techniques of industrial engineering in shipbuilding</b> | The aim of the course is to introduce the students with the basic methods and techniques of industrial engineering that can be used to increase efficiency and effectiveness in shipbuilding. The given methods and techniques will enable students to develop organizational and management skills for planning, budgeting, organizing, leading and controlling tasks, people and resources and managing quality, costs, time and risks in shipbuilding. | Successful completion of this course raises students' awareness of the importance of organizational and management skills in engineering activities and prepares them for commercial leadership in shipbuilding. The acquisition of knowledge in the field of basic - modern theoretical concepts and empirical methods and techniques in industrial engineering relevant to shipbuilding is emphasized.                                                                                                                                                                                                                                   |
| 3.4 | fluid mechanics        | 1559 | elective   | <b>Computational Fluid Dynamics (CFD)</b>                                              | 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.                                                                                                                                                                                                                     | Upon successful completion of the course, students will be able to: <ul style="list-style-type: none"> <li>- explain the general principles of numerical solution of governing equations for fluid flow</li> <li>- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow</li> <li>- explain and apply principles of numerical grid generation</li> <li>- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)</li> <li>- use OpenFOAM solvers for determining the</li> </ul> |

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|     |                        |      |          |                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <p>solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in various domains</p> <ul style="list-style-type: none"> <li>- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 3.4 | production engineering | 0920 | elective | <b>Machine tools M</b> | <ol style="list-style-type: none"> <li>1. To develop ability to perceive typical missions of machining systems.</li> <li>2. To study machine tools mechanisms and systems for their control and programming.</li> <li>3. To receive training in testing procedures for machine tools.</li> <li>4. To develop ability to analyze complex machine tools and machining systems equipment.</li> <li>5. The develop ability to analyze the resources for machine tools development.</li> <li>6. To study configuring and/or building of machine tools for planned mission.</li> <li>7. To receive training for realization of one mission of machine tools through writing the seminar work.</li> <li>8. To know how to make technical projects.</li> </ol> | <p>Upon successful completion of this course students should be able to:</p> <ol style="list-style-type: none"> <li>1. Recognize typical missions of manufacturing systems.</li> <li>2. Apply basic types of machine tool mechanisms in their design.</li> <li>3. Configure the control of CNC machine tools based on systems with open architecture.</li> <li>4. Program new generation machine tools using different programming methods.</li> <li>5. Evaluate the quality of machine tools and machining system based on applied standard test procedures.</li> <li>6. Configure machine tool for their own needs.</li> <li>7. Apply the acquired knowledge on the available resource for the development and / or improvement of machine tools and manufacturing systems.</li> <li>8. Prepare Technical Elaborate and reports about testing and programming of machine tools.</li> </ol> |
| 3.4 | naval systems          | 1563 | elective | <b>Ship</b>            | Within the course, students are introduced to the basic principles of ship                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <ol style="list-style-type: none"> <li>1. The student gains a comprehensive understanding of the fundamental challenges</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

manoeuvrability, in order to ensure safe control of the ship's trajectory during navigation. In this context, students are familiarized with standard procedures for assessment and criteria for evaluating the manoeuvrability of existing ships. Additionally, they become acquainted with the relevant regulations established by ITTC and IMO governing ship manoeuvrability. Students are comprehensively introduced to both theoretical and experimental methods utilized in ship design, with the aim of achieving the necessary manoeuvring characteristics. In addition, students acquire essential knowledge of the technical specifications of existing control devices utilized for steering the ship during navigation.

associated with ship manoeuvrability, along with the basic manoeuvring characteristics specific to seagoing displacement ships.

2. The student can effectively apply comprehensive knowledge in mathematics, rigid body dynamics, fluid mechanics and basic engineering principles to determine and analyze the manoeuvring performances of a ship.

3. The student is trained to critically assess how primary and secondary characteristics of hull form and control devices affect manoeuvrability, employing fundamental principles of natural sciences. This analysis aims to optimize ship design to enhance manoeuvrability.

4. The student is qualified to select and apply appropriate empirical, numerical, and experimental methods to assess the impact of basic parameters of hull form and control devices on the manoeuvring capabilities of the ship, considering the limitations of the waterway, as well as the constraints of the chosen methods.

5. The student can choose and critically evaluate relevant technical literature and other sources of information for solving complex problems in the field of marine hydrodynamics with a particular focus on ship manoeuvrability.

6. The acquired knowledge enables the student to address complex engineering challenges and meet specific design requirements imposed by contemporary trends in naval architecture, particularly those related to ship manoeuvrability. This is notably apparent in the case of full-form ships, which may lack directional stability,

necessitating the implementation of innovative technical solutions within confined spaces to ensure the vessel's safety.

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| 3.5 | strength of structures | 1576 | elective | <b>Composite plates and beams</b>          | <p>Main objective of the course is to teach students the fundamental principles of the mechanics of laminated composite plates and beams. This theory is applied to analyze unidirectional and multidirectional fiber reinforced composite plates and beams. Within the course the basics associated with the design of composite plates and beams will be studied as well. A special attention will be devoted to the practical stress and strain analysis of structural components made out of laminated composite materials which are subject to tension (compression), bending and torsion.</p> | <ol style="list-style-type: none"> <li>1. Within the course students will learn various methods for determining elasticity constants for one layer of composite material (lamina), as well as, ways of assessment of stiffness matrix for multi-layered composite material (laminate). Students will also learn to define carrying capacity of composite plates and beams in case when mechanical properties of each layer of composite material are known. Students will learn how to apply different failure criteria.</li> <li>2. Students will learn how to perform stress – strain analysis of laminated composite plates and beams.</li> <li>3. Within the course students will learn to analyse the influence of the environmental conditions (e.g. temperature and humidity) on mechanical properties of laminated composite materials.</li> <li>4. By completing this course students will become familiar with fundamentals of mechanics of composite plates and beams. A special attention will be devoted to the practical implementation of composite plates and beam as structural elements.</li> </ol> |
| 3.5 | naval systems          | 1564 | elective | <b>Software application in Ship design</b> | <p>The aim of the course is to cover the application of software packages for ship design and basic calculations in shipbuilding. With the help of software packages, the student should analyze and optimize the ship from the perspectives of safety, efficiency, and environmental acceptability.</p>                                                                                                                                                                                                                                                                                            | <p>Acquisition of practical knowledge in the application of computer programs for ship form development, hydrostatic and hydrodynamic calculations, optimization of ship form using CFD, prediction of ship engine power, selection of ship construction elements, ship behavior in waves, and ship design.</p> <p>The student will be equipped to apply</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

comprehensive knowledge from mathematics, statistics, natural sciences, and engineering principles to solve complex problems, supplemented by critical awareness of engineering development and broader engineering context, including formulating, analyzing, and evaluating available data to draw informed conclusions and applying engineering reasoning when dealing with uncertain or incomplete information in ship design. The student will be able to choose and apply appropriate computational and analytical techniques for modeling complex problems, apply an integrated or systemic approach to problem-solving, and use practical laboratory and workshop skills for problem investigation, considering constraints of applied techniques in the domain of shipbuilding.

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| 3.5 | hydropower engineering | 1423 | elective   | <b>Pumps and fans</b>       | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function. | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density. |
| 4.1 | naval systems          | 1220 | obligatory | <b>Skill Praxis M - BRO</b> | The student gains practical experience in the occupational environment where he will pursue his future career. He identifies                                                                                                                                                | The student should gain practical experience in the way of organizing and functioning of the environment where he will apply the acquired                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

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|     |   |      |            | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b><br>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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. | Upon the successful completion of M.Sc. Thesis Project, engineers should be able to: <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-</li> </ul> |

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|     |   |      |            |                     | critically;<br><ul style="list-style-type: none"> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Process Engineering and Environment Protection

| position | department                                       | ID   |            | title                                                          | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
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| 1.1      | process and environmental protection engineering | 1056 | obligatory | <b>Transport phenomena in process industry</b>                 | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 1.2      | process and environmental protection engineering | 0991 | obligatory | <b>Mechanical and hydromechanical Operations and Equipment</b> | 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. | 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. |
| 1.3      | fluid mechanics                                  | 1290 | elective   | <b>Fluid Mechanics</b>                                         | Main goal is to learn student general                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Student will gain knowledge on general principles in                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

**M**

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.

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.

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| 1.3 | mechanics     | 0004 | elective | <b>Mechanics M</b>    | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Reza theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.4 | thermomechani | 0202 | elective | <b>Thermodynamics</b> | <p>Student should gain knowledge in</p>                                                                                                                                                                                                                                                                                                                                                                                               | <p>Upon successful completion of this course, students</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

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.

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.

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b> | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.</p> <p>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p> | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p> |
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| 1.5 | process and environmental protection engineering | 0477 | elective | <b>Measurements and Control in Process Industry</b> | Introducing the candidate with the principles of process measurement and control of the process using the measured values. After the course candidates will be capable to independently perform statistical processing of measurement results and evaluation of measurement uncertainty. The process of accreditation of laboratories and regulatory organizations. | Upon completion of the course is expected that the candidate is familiar with the basic measurements and instruments used in measurement and control in process systems. Also it is expected that the student is able to independently plan experimental measurements and work in laboratory and also to evaluate the measurement uncertainty. Basic knowledge about the accreditation of laboratories candidate receives through the consideration of the basic requirements of relevant standards.                                                                                                                                                                                                                                                   |
| 1.5 | mathematics                                      | 0354 | elective | <b>Probability and statistics</b>                   | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                                                                                                         | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> <li>2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.</li> <li>3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.</li> <li>4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.</li> <li>5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.</li> </ol> |

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 1.5 | fluid mechanics                                  | 1558 | elective   | <b>Transport of fluid through pipes</b>       | The goal of studying the subject is to learn and study important engineering problems related to the pipeline transport of fluids, and especially to the calculation methods 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, methods of pipe support and techno-economic analysis of pipeline transport.                      | As a result of studying the subject, mastering theoretical assumptions, physical laws, approximations and calculation methods of one-dimensional fluid flows through special purpose pipelines, such as: water pipelines, hot water pipelines, oil pipelines, gas pipelines and steam pipelines. As a result of the course, practical knowledge is obtained to solve technical problems: water hammer in pipelines, corrosion of pipelines, thermal expansion of pipelines and ways of supporting pipes. |
| 2.1 | process and environmental protection engineering | 1057 | obligatory | <b>Heat transfer operations and equipment</b> | 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.                                                                                                                                                                                                                       | The mastery of calculation procedures needed to analyze the heat transfer operations - the balance of energy, determination of the operational line and driving force.<br>The mastery of calculation procedures for sizing of the most commonly used heat transfer apparatuses.                                                                                                                                                                                                                          |
| 2.2 | process and environmental protection engineering | 1264 | obligatory | <b>Biotechnology</b>                          | 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. | 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.                                                                                                     |

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| 2.3 | process and environmental protection engineering | 0301 | obligatory | <b>Chemical and Biochemical Operations and Reactors</b> | 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. | 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. |
| 2.4 | process and environmental protection engineering | 1123 | elective   | <b>Processes and Equipment for water treatment</b>      | The aim of the course is to give students the academic skills and competencies to monitor the process as well as the selection and designing appliances and devices used for water treatment. Through the term paper students acquire creative ability and specific practical skills for performing tasks within their profession, process monitoring and design of process equipment.                                                                                                                                                                                                                                    | After successful course attending students get ability for: analysis, synthesis and predicting solutions and consequences; developing of critic and self-critic judgment and approach; practical implementation of knowledge; professional ethic; connecting knowledge from different areas and their implementation; developing skills and abilities for knowledge implementation in adequate area.                                                                                           |
| 2.4 | process and environmental protection engineering | 0993 | elective   | <b>Furnaces and boilers in industry</b>                 | In this course students will acquire necessary knowledge and skills for designing, maintenance and operation of industrial furnaces, and basic skills required for the maintenance and operation of industrial boilers.                                                                                                                                                                                                                                                                                                                                                                                                   | Students will gain necessary skills to work on design and the organization of maintenance in industrial furnaces, and the planning of maintenance and operation of industrial boilers. Students will be trained for work on the projects for energy efficiency in industrial furnaces and boilers.                                                                                                                                                                                             |

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|     |                                    |      |          |                       | Additionally, students will learn about methodology on energy balances and the basic principles of efficient use of energy in industrial furnaces and boilers.                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>    | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design. | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                                                                                                                                                                                                                                                                                                                                       |
| 2.4 | hydropower engineering             | 1001 | elective | <b>Turbomachinery</b> | Theoretical background in turbomachinery basic principles. Practical, engineering knowledge in turbomachinery and their applications, with focus on rotodynamic pumps, fans and turbocompressors.                                                                                                                                                                                                                  | Upon successful completion of this course, students should be able to: <ol style="list-style-type: none"> <li>1. identify and describe the various types and constructions of turbomachinery, as well as the principles of their work,</li> <li>2. calculate and apply dimensionless parameters (characteristic coefficients),</li> <li>3. determine the duty point of the hydraulic turbomachine and system,</li> <li>4. select the appropriate pump or fan, as well as the most energy efficient way of their regulation,</li> <li>5. calculate the pump duty point in terms of cavitation,</li> <li>6. calculate the thermodynamic and energy parameters of the turbocompressor,</li> <li>7. plan the fan testing according to the international standard.</li> </ol> |

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| 2.5 | process and environmental protection engineering | 1124 | elective | <b>Principles of environmental and work space protection</b> | The main course objectives are related to introduce students to environmental problems, natural hazards and human impact on the environment. In order to solve problems, students will be acquainted with the physics and chemistry of the environment, atmospheric phenomena, the basics of microbiology and ecology.                                                                                                              | Based on lessons envisaged to overcome the students will be able to make independent decisions related to environmental management, sustainable development, impact assessment of projects and facilities on the environment. Especially important is the knowledge that students acquire in terms of life cycle analysis of products and processes.                                                                                                                                                                                |
| 2.5 | process and environmental protection engineering | 1059 | elective | <b>Energy in process engineering</b>                         | Mastering the basic knowledge and skills of using the energy in process industry in order to adequately deal with the practical matters of rational use of energy and maintenance of energy equipment and systems in industrial companies. In addition, basic knowledge of the transformation and energy use are essential for the understanding of matter from other subjects of process engineering and environmental protection. | Understanding the operation of energy equipment and technologies and principles of their rational use. Preparation of the energy balance of industrial companies; implementation of energy auditing procedure, energy data collection and implementation of methodology for defining the energy losses of equipment and installations in industrial plants. Understanding basic terms within Energy Management System (ISO 50001:2011). Basic concept of BAT (Best Available Techniques) in energy efficiency in industrial plants. |
| 2.5 | thermal power engineering                        | 0325 | elective | <b>Two-Phase Flows with Phase Transition</b>                 | 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.                                                                                             | 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.                                                                                                                                                                                                                                                                                                        |
| 2.5 | fluid mechanics                                  | 1011 | elective | <b>Gas Dynamics</b>                                          | The student should:<br>1. acquire basic theoretical knowledge in                                                                                                                                                                                                                                                                                                                                                                    | Attendance and regular monitoring of the theoretical and practical training the student should                                                                                                                                                                                                                                                                                                                                                                                                                                      |

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|     |                                                  |      |            |                                                                 | <p>the field of gas dynamics;</p> <p>2. be trained to perform basic engineering calculations of compressible flows;</p> <p>3. become familiar with the basic procedures for experimental research in gas dynamics.</p>                                                                                                                                                                                                                                                                                                                       | <p>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.</p>                                                                                     |
| 3.1 | process and environmental protection engineering | 0363 | obligatory | <b>Design, construction and operation of processing systems</b> | <p>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.</p> | <p>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.</p> |
| 3.2 | process and environmental protection engineering | 1372 | obligatory | <b>Mass transfer and equipment</b>                              | <p>Analysis of the mass transfer operations and apparatuses and assessment of their role in modern industry.</p> <p>Understanding the most commonly used types of mass transfer apparatuses - their design and calculation procedures.</p>                                                                                                                                                                                                                                                                                                   | <p>The mastery of calculation procedures needed to analyze the mass transfer operations - the material balance, determination of the operational line and driving force.</p> <p>The mastery of calculation procedures for sizing of the most commonly used mass transfer apparatuses.</p>                                                                                              |
| 3.3 | process and environmental protection engineering | 0124 | obligatory | <b>Air Pollution Control</b>                                    | <p>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</p>                                                                                                                                                                                                                                                                                                                                | <p>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</p>                                                                                                                           |

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|     |                                                  |      |            |                                                 | purification of gases and review of methodology for calculations commonly used types of these devices. In this way the student masters the skills of designing these facilities and individual devices.                                                                                                                                                                | 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.                                                                                                                                                                                                                                                    |
| 3.3 | process and environmental protection engineering | 0125 | obligatory | <b>Waste and wastewater management</b>          | 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.                                                                                              | 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.                                                                                                                                                                                                                                        |
| 3.4 | process and environmental protection engineering | 1062 | elective   | <b>Maintenance in process industry</b>          | The objective of the course is that students acquire theoretical and practical knowledge in the field of maintenance of technical systems (concept, technology...). Through teaching activities, students acquire creative and specific practical skills that qualify them to work in the field of maintenance of equipment, machines and systems in process industry. | By successful completion of the study program student acquires the following skills: analysis, synthesis and prediction of solutions and consequences in the field of maintenance in process industry; development of critical thinking and self-critical approach; application of knowledge in practice; professional ethics; correlation of knowledge from different fields and their applications; involvement in the activities related to maintenance in the company. |
| 3.4 | process and environmental protection engineering | 1061 | elective   | <b>Economic analysis in process engineering</b> | Familiarize students with the basic concepts of economic analysis, through the study of the capital and operating costs, shortcut methods of economic optimization and economic analysis of investment.                                                                                                                                                                | Students will be able to:<br>* calculate the investment costs<br>* calculate the operating costs<br>* determine the economic parameters of investment profitability<br>* use the shortcut procedures for determining of the optimal pipeline diameter and optimal insulation thickness                                                                                                                                                                                     |
| 3.4 | process and                                      | 0511 | elective   | <b>Combustible,</b>                             | The aim of this course is to familiarize                                                                                                                                                                                                                                                                                                                               | Successful completion of the study program the                                                                                                                                                                                                                                                                                                                                                                                                                             |

|     |                                      |      |          |                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
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|     | environmental protection engineering |      |          | <b>technical and medical gases</b>                          | students with the fuel characteristics, technical and medical gases, and to acquire academic skills and competencies for selection and calculation of equipment of gas installations. Through this course student mastery specific practical skills for work in the design and calculation of pipelines and fittings, storage tanks and other equipment for gas. Through laboratory student acquire knowledge related to testing of equipment for gas.                                                                                                                                                                                                     | student receives the following general skills: analysis, synthesis and forecasting solutions and consequences, and develop critical thinking and self-critical approach, application of knowledge in practice, professional ethics, linking knowledge from different fields and their applications, development of skill and dexterity in the use of knowledge in the field of distribution and transportation of natural gas storage and technical gases.                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 3.4 | hydropower engineering               | 0928 | elective | <b>Renewable energy resources - small hydropower plants</b> | <p>Achieving academic competence in the field of small hydropower plants, hydromechanical equipment and hydro energy.</p> <p>Obtaining practical knowledge in small hydropower plants designing and the content of the technical project documentation.</p> <p>Mastering knowledge of how to choose and calculate hydromechanical equipment installed in small hydroelectric stations.</p> <p>Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.</p> <p>Improving individual creative abilities in performing professional design of small</p> | <p>On successful completion of this course the students will be able to:</p> <ul style="list-style-type: none"> <li>- define, plan and organize the phases of project design, build up and operation of small hydropower plants,</li> <li>- 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,</li> <li>- check the adopted geometry and operating characteristics by basic analysis of the transient operating regimes and water hammer phenomenon,</li> <li>- collect, analyze and present the calculation results,</li> <li>- choose the best solution to the specific case by analyzing more possible solutions from the point of energy efficiency,</li> <li>- work as a part of a team as well as demonstrate their entrepreneurial skills.</li> </ul> |
| 3.5 | process and                          | 1063 | elective | <b>Draying and</b>                                          | Students will be introduced to technical                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Successful completion of the study program                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

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|     | environmental protection engineering             |      |          | <b>dryers</b>                           | bases of materials drying process. The goal of this course is a review of the dryers basic constructions. Through this course students acquire skills and knowledge to recognize problems that occur in complex drying processes.                                                                                      | student acquires specific skills in function of quality performance of professional activities. It is anticipated that students acquire knowledge on specific technical solutions in the fields of drying materials, as well as being able to analyze complex technical solutions.                                                                                                                                                                                  |
| 3.5 | thermal science engineering                      | 1545 | elective | <b>Industrial cooling facilities</b>    | Achieving competencies and academic skills as well as methods for their acquisition. Development of creative abilities and mastery of practical skills specific to performing the profession. The goals are concrete and achievable and fully in line with the established basic tasks and goals of the study program. | 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.                                                                                                                                                 |
| 3.5 | process and environmental protection engineering | 1373 | elective | <b>Design of fire protection systms</b> | Introducing students with fire safety analyzes, preventive regulations on fire protection, fire characteristics of industrial objects and buildings, fire extinguishers and installations for smoke ventilation                                                                                                        | Students will be able to overcome the basis of fire safety analyzes, preventive regulations on fire protection, fire characteristics of industrial objects and buildings, fire extinguishers and installations for smoke ventilation                                                                                                                                                                                                                                |
| 3.5 | process and environmental protection engineering | 0997 | elective | <b>Technical legislation</b>            | Objective of the course is that students acquire academic skills and academic competencies for application of technical legislation. Through teaching activities, students acquire creative and specific practical skills that qualify them to work in their professional field - design.                              | By successful completion of the study program student acquires the following skills: analysis, synthesis and prediction of solutions and consequences; development of critical thinking and self-critical approach; application of knowledge in practice; professional ethics; correlation of knowledge from different fields and their applications; development of skill and proficiency in the use of knowledge in field of technical documentation preparation. |
| 3.5 | process and                                      | 1180 | elective | <b>Analysis and risk</b>                | Introducing students with risk analysis,                                                                                                                                                                                                                                                                               | Students will overcome the basic concepts in the                                                                                                                                                                                                                                                                                                                                                                                                                    |

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|     | environmental protection engineering             |      |            | <b>management in process industries</b> | risk management and risk engineering in the field of process industries                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | field of risk analysis, as well as the engineering approach to risk management                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 4.1 | process and environmental protection engineering | 1550 | obligatory | <b>Skill praxis M - PTH</b>             | 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.                                                                                                                                                                                                                                                       | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 4.3 | -                                                | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>           | Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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. | <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate</li> </ul> |

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|     |   |      |            |                     | <p>conclusions;</p> <ul style="list-style-type: none"> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                    |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Production Engineering

| position | department             | ID   |            | title                           | goal                                                                                                                                                                                                                                                                                                                                        | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
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| 1.1      | production engineering | 0785 | obligatory | <b>Manufacturing Automation</b> | 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          | After successfully completing this course, the students should be capable to: <ul style="list-style-type: none"> <li>- Analyze social, economic, production and other effects of automation;</li> <li>- Integrate knowledge in related subjects and implement them in automation;</li> <li>- Analyze and synthesize combinational automata;</li> <li>- Synthesize sequential automata;</li> <li>- Carry out pneumatic and electro-pneumatic realization of combinational and sequential automata;</li> <li>- Program programmable logic controllers according to IEC 61131-3.</li> </ul>                                                                                                                                    |
| 1.2      | production engineering | 1106 | obligatory | <b>Industrial robots</b>        | 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. | After completed this course the students should be able to: <ul style="list-style-type: none"> <li>• Understand the role and importance of industrial robots application (effects on productivity, flexibility, product quality and humanization of work).</li> <li>• Solve the problem of robot introducing to the plant/factory.</li> <li>• Select appropriate robot configuration, end-effector and peripheral equipment for given technological task.</li> <li>• Design robotized workplace taking into account cycle time analysis as well as techno-economic analysis (pay back analysis).</li> <li>• Programming the robots as well as robotized cell.</li> <li>• Design the basic manipulator mechanical</li> </ul> |

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|     |                 |      |          |                          |                                                                                                                                                                                                                                                                                                                                                                                                                                       | subsystems as well as select the appropriate components.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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:</p>                                                                                                                                                                                                                |

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|     |                                   |      |          |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | incompressible and compressible flow in pipes and nozzles.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.<br>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.                                                                                                                                                                              | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• Recognize and determine the thermodynamic</li> </ul> |

properties of wet gases and implement them in the analysis of thermomechanical processes in devices and facilities with moist air.

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| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b>            | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines. | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;</li> <li>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;</li> <li>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;</li> <li>4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.</li> </ol> <p>Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.</p> <p>Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.</p> |
| 1.5 | production engineering             | 1166 | elective | <b>Coordinate Measuring Machines</b> | 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 in production engineering. Students should acquire and to master new knowledge and skills                                                                                                | 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

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|     |                        |      |          |                                     | about: basic terms in production metrology, 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 inspection and measurement. | 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.                                                                                                                                             |
| 1.5 | production engineering | 1362 | elective | <b>Sheet-Metal Processing Tools</b> | 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.                                               | <p>On successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Evaluate each element of the tool for its construction and function with respect to the material and performance.</li> <li>• 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.</li> <li>• Identify different concepts and specificities of sheet-metal processing tools.</li> <li>• Create a concept of a sheet-metal processing tool for a specified part.</li> </ul> |
| 1.5 | mathematics            | 0354 | elective | <b>Probability and statistics</b>   | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.                                                                                                                                                                                                                             | <p>Upon successful completion of this course, students should be able to:</p> <p>1) Calculate probability and conditional probability of random events.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.

3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.

4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.

5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

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| 2.1 | production engineering | 1534 | obligatory | <b>Manufacturing Systems Design</b> | <p>1. Understanding the structure of the modern machining systems, the functions of the basic subsystems and their interactions.</p> <p>2. Application of methodological frameworks of developed design theories.</p> <p>3. Study of static and dynamic properties of the machining system and optimization methodology of its mechanical structures</p> <p>4. Application of modern CAD/CAM/CAE systems for simulating static and dynamic behavior of mechanical structures of machining systems</p> | <p>Upon successful completion of this course, students should be able to:</p> <p>1. Within the methodological framework of the design theory formulates functional requirements, design parameters and the design matrix at all levels of the design process of one product and implements the necessary corrections that lead to the optimization of the design solution.</p> <p>2. Set up the concept of a static model of the concrete supporting structure of the machining system, with the necessary simplifications of the real model, define the model of the support system and external load, generate a discretized model</p> |
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5. Gaining practical experience in experimental identification of static and dynamic properties of supporting structures

6. Application of modern software environments in the creation of a virtual prototype of a machine system

7. Practical experience in drafting technical reports.

using the finite element method (FEM), perform simulation in the selected program environment for FEM analysis and explain the obtained results: displacements, stresses and reactions of supports;

3. Set up the concept of a dynamic model of the concrete supporting structure of the processing system, define a model of the support system, define a simplified model, mass characteristics and generate a discretized model using the finite element method (FEM), calculate the natural frequencies and forms of oscillation using a computer and explain the results obtained;

4. Creating a setup for experimental identification of parameters of static and dynamic behavior of a mechanical structure;

5. Possesses the necessary knowledge for designing a machine system (transmission for spindle system, transmissions for feed drives, main spindles of machine tools), in the form of analytical models, standards, market of specialized components, and already realized design solutions.

6. Uses modern software environments in creating a virtual prototype of a machine system or its subsystem;

7. Conceptualizes a technical elaboration, which refers to the considered design solution or performed tests, in the field of processing systems.

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| 2.2 | production engineering | 1529 | obligatory | <b>Computer Integrated Manufacturing Systems and</b> | A detailed study of the principles and application of computer integrated manufacturing. Advanced concepts and models related to computer-aided design, |
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This course will enable the student to:

- apply knowledge of modeling, simulation and visualization in industrial applications,
- design CIM systems that satisfy the given

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|     |                                    |      |            | <b>Technology</b>                     | computer-aided process planning,<br>computer aided manufacturing,<br>production planning and scheduling.                                                                                                                                                                                                                                                                                                         | conditions,<br><ul style="list-style-type: none"> <li>• identify and solve problems in the operation of the CIM system,</li> <li>• improve the performance of manufacturing systems using different CIM concepts and tools,</li> <li>• handle production data and the different software used in production.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 2.3 | production engineering             | 0786 | obligatory | <b>PRODUCTION INFORMATION SYSTEMS</b> | 1.Acquisition of knowledge about the role and importance of computer-oriented information systems for planning and management of production systems<br>2. Mastery of theoretical basics of contemporary information systems architecture<br>3. Acquisition of practical knowledge for applications design and development in the domain of information systems for planning and management of production systems | On successful completion of the course, students should be able to:<br><br><ul style="list-style-type: none"> <li>•Identify basic concepts in the sphere of computer-oriented information systems design and development.</li> <li>•Identify the application and role of contemporary database management systems.</li> <li>•Define sub-systems (modules) within the production system, documentation and information flows within the sub-system and their interactions within the overall system.</li> <li>•Design database logical structure for a corresponding technological sub-system with description of required attributes for each entity and links between the entities.</li> <li>•Use contemporary software tools in the design and development of production information systems.</li> </ul> |
| 2.4 | physics and electrical engineering | 1324 | elective   | <b>Electronics</b>                    | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge                                                                                                                                                                                                                                                                   | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

|     |                        |      |          |                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
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|     |                        |      |          |                                            | and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.                                                                                                                                                                                                                                | of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 2.4 | production engineering | 1314 | elective | <b>Additive Manufacturing Technologies</b> | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Recognize the basic differences between methods of material removal, material shaping and adding material (additive technologies)</li> <li>• Distinguish methods of additive manufacturing</li> <li>• Compare methods of additive manufacturing</li> <li>• Analyze the possibility of using additive technologies</li> <li>• Depending on the load of the structure and its purpose, they prescribe the appropriate type if additive technology, as well as modes of manufacturing</li> <li>• Generate a computer model of the work: CAD and scanning</li> <li>• Use generative methods (approaches) of designing based on natural method of construction</li> <li>• Optimize the geometry of the structure according to the conditions of additive technologies</li> <li>• Prepare for manufacturing</li> <li>• Design and calculate a processing system intended for additive manufacturing technologies.</li> </ul> |
| 2.4 | mechanics              | 0037 | elective | <b>Theory of Mechanical Vibrations</b>     | 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.                                                                                                                                                                                                                                                                               | Upon successful completion of this course, students will be able to: <ul style="list-style-type: none"> <li>• Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

- 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.
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- 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.

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| 2.4 | production engineering | 1536 | elective | <b>Mechatronics Systems</b> | The goal of the course in mechatronic systems is to provide a focused interdisciplinary theoretical knowledge and practical experience for students that | After successfully completing the course, student is capable to:<br>1. Analyze project task referring to production processes and define concept of mechatronic |
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encompass fundamental elements from traditional courses in mechanical engineering, production engineering, electronics and computer control engineering.

system using multi-disciplinary approach;  
 2. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with digital input-output signals;  
 3. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with analog and mixed input-output signals;  
 4. Configure hardware and input-output channels and other system resources of an integrated microprocessor system, create application software for serial communication with the digital environment, including serial communication with a personal computer;

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| 2.5 | production engineering | 0722 | elective | <b>Computer Simulation in Manufacturing Automation</b> | <p>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</p> | <p>After successfully completing this course, the students should be capable to:</p> <ul style="list-style-type: none"> <li>- Create and implement stochastic simulation;</li> <li>- Create conceptual model for discrete event simulation;</li> <li>- Create and implement discrete event simulation within fixed and flexible automation framework;</li> <li>- Create conceptual and computer model for continuous simulation of various processes;</li> <li>- Integrate continuous and discrete event simulation;</li> <li>- Manage discrete event simulation project.</li> </ul> |
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| 2.5 | production engineering | 1107 | elective | <b>New generation of machine tools and robots</b> | <p>1. Perception of different levels of the new generation of machine tools and robots concept.</p> <p>2. Acquisition of basics of reconfigurable, high-speed, meso- and micro-machines and highaccuracy machine tools.</p> <p>3. Practical knowledge about parallel kinematic machines and machines for material addition processes and multi-axis machining.</p> <p>4. Development of programming skills relevant for the new generation of machine tools and robots.</p> <p>5. Development of report-making skills.</p>                                                                                | <p>After completed this course the students should be able to:</p> <ul style="list-style-type: none"> <li>•Understand the role, importance, types and applications of the new generation of machine tools and robots.</li> <li>•Understand different levels of the new generation of machine tools and robots concept.</li> <li>•Select appropriate new generation machine tools and robots for given technological task.</li> <li>•Select and prepare environment for operation of machine tools and robots.</li> <li>•Programming the new generation of machine tools and robots.</li> <li>•Use new programming methods for numerically controlled systems.</li> </ul>                                                                  |
| 2.5 | strength of structures | 0721 | elective | <b>Basics of Composite Materials Mechanics</b>    | <p>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</p> | <p>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.</p> <p>2. Students will learn how to perform stress – strain analysis of laminate composite materials.</p> <p>3. The course will devote some attention to the influence of the environmental conditions (e.g. temperature and humidity) to the variation of</p> |

tackled as well.

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.

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| 2.5 | industrial engineering | 1370 | elective   | <b>Design of logistic and warehouse systems</b> | 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.                  | 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.                                                                                                                                                                                                                                           |
| 3.1 | production engineering | 0104 | obligatory | <b>New Technologies</b>                         | 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. | On successful completion of the course, students should be able to: <ul style="list-style-type: none"> <li>•Design technology for building complex machine parts from various materials (metal, metal powder, polymer, ceramic, stone, etc.).</li> <li>•Design technology for manufacturing of cutting tools (powder metallurgy).</li> <li>•Identify versatile specificities of plastic parts pressure casting tools, stamping tools for metal parts.</li> <li>•Use some of the advanced software tools for</li> </ul> |

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|     |                        |      |            |                                          | simulations of the polymer material parts pressure casting process, along with analysis and presentation of experimentally obtained results.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|     |                        |      |            |                                          | <ul style="list-style-type: none"> <li>•Draft a plastic parts pressure casting tool for a specified part.</li> <li>•Apply some of the developed CAD/CAE/CAM software tools for modeling drafted polymer material parts pressure casting tools.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 3.2 | production engineering | 1167 | obligatory | <b>Quality Management</b>                | <p>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 scientific-professional work of students and engineers in production engineering. 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 statistical techniques of quality engineering; 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 9000 series.</p> <p>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 9001 for the organization; prepare and implement a TQM project for the organization.</p> |
| 3.3 | production engineering | 0131 | obligatory | <b>Intelligent manufacturing systems</b> | <p>The aim of the course is to develop students' ability for conceptual design and implementation of intelligent</p> <p>Students' learning outcomes of this course are:</p> <ul style="list-style-type: none"> <li>• Implementation of developed software tools (e.g. TRIZ, Flexy) for modelling and analysis of intelligent</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

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|     |                        |      |          |                                            | <p>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.</p> | <p>manufacturing systems and processes.</p> <ul style="list-style-type: none"> <li>• 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.</li> <li>• Advanced utilization of the software for discrete event simulation (AnyLogic, Flexy) with analysis and presentation of the experimental results obtained.</li> <li>• Understanding the interaction of soft and hard real-time subsystems of autonomous mobile robot through reconfiguration and advanced programming in MATLAB.</li> <li>• Capability for team work.</li> </ul> |
| 3.4 | general machine design | 1444 | elective | <b>Technical regulations and standards</b> | <p>Acquiring of the 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.</p>                                                                                                                                                                                                                                                                                                                                 | <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                  |
| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and</b>        | <p>Students acquaintance with the goals of techno-economic analysis and the goals, processes and stages of project</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

**project  
management**

management. Acquaintance and mastering with modern methods, techniques, tools and areas of knowledge necessary for successful project management.

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.

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| 3.4 | production engineering | 0920 | elective | <b>Machine tools M</b> | <ol style="list-style-type: none"><li>1. To develop ability to perceive typical missions of machining systems.</li><li>2. To study machine tools mechanisms and systems for their control and programming.</li><li>3. To receive training in testing procedures for machine tools.</li><li>4. To develop ability to analyze complex machine tools and machining systems equipment.</li><li>5. The develop ability to analyze the</li></ol> | <p>Upon successful completion of this course students should be able to:</p> <ol style="list-style-type: none"><li>1. Recognize typical missions of manufacturing systems.</li><li>2. Apply basic types of machine tool mechanisms in their design.</li><li>3. Configure the control of CNC machine tools based on systems with open architecture.</li><li>4. Program new generation machine tools using different programming methods.</li></ol> |
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|     |                           |      |          |                             | <p>resources for machine tools development.</p> <p>6. To study configuring and/or building of machine tools for planned mission.</p> <p>7. To receive training for realization of one mission of machine tools through writing the seminar work.</p> <p>8. To know how to make technical projects.</p>                                                                                                                                                                                                                                                                                                                                                                               | <p>5. Evaluate the quality of machine tools and machining system based on applied standard test procedures.</p> <p>6. Configure machine tool for their own needs.</p> <p>7. Apply the acquired knowledge on the available resource for the development and / or improvement of machine tools and manufacturing systems.</p> <p>8. Prepare Technical Elaborate and reports about testing and programming of machine tools.</p>                                                                                                                                                                                                                                                                  |
| 3.4 | production engineering    | 1535 | elective | <b>Assembly Technology</b>  | <p>1. Learning of systematic approach to the design and production of mechanical assemblies;</p> <p>2. Understanding assembly process and basic assembly operations;</p> <p>3. Impact of assembly process on product development – product structure and Design For Assembly techniques;</p> <p>4. Part mating process, modeling and understanding relationships between precision, sensitivity and flexibility;</p> <p>5. Basic concepts of assembly systems – manual, automatic and robotic systems; Assembly system design; Assembly workstation design issues;</p> <p>6. Performance and Economics of Assembly Systems;</p> <p>7. Product lifecycle and product disassembly.</p> | <p>After successfully completing course, student is capable to:</p> <p>1. Analyze assembly and carry out its optimal sequencing into basic assembly operations for the given set of criteria;</p> <p>2. Design a system for automatic assembly that includes parts feeding, orientation, separation and geometry control;</p> <p>3. Design systems for manual assembly with all sub-systems including sequencing;</p> <p>4. Design systems for automatic and robotized assembly including work stations, as well as peripherals for parts feeding;</p> <p>5. Optimize assembly design with respect to its assemblability using qualitative and quantitative Design for Assembly techniques</p> |
| 3.5 | engineering materials and | 0537 | elective | <b>Tribological systems</b> | <p>The student attending this course should:</p> <ul style="list-style-type: none"> <li>• Comprehend the issue and the</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p>Based on the mastered knowledge the student is qualified to:</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

welding,  
tribology, fuels  
and combustion

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.

- 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.

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| 3.5 | production engineering | 0601 | elective | <b>Micro Manufacturing and Characterization</b> | <p>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.</p> | <p>At the end of this course students will be able to:</p> <p>Apply basic principles of manufacturing in the micron area</p> <p>Identify the different machine and tools, industrial robots, assembly and transport systems and automation systems applicable to micro manufacturing</p> <p>Select the suitable methods of micro manufacturing according to techno-economic criteria.</p> <p>Select the principle of measurement and characterization of functional primitives</p> <p>Understanding the properties of the material adequate for micro manufacturing.</p> <p>Apply scientific methods of analysis, synthesis and design, as well as computer technology</p> |
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| 3.5 | production engineering | 1537 | elective   | <b>Computer control and monitoring in manufacturing automation</b> | The goal of the course is for students to acquire the necessary knowledge in the application, design, and implementation of modern computer control and monitoring systems in manufacturing automation, as well as to get skills for solving practical problems of computer control and monitoring in automation. | After completing this course the students should be able to: 1. Apply a stepper motor to actuate a mechanical system within the manufacturing process, including designing the hardware architecture and control system based on integrated microcontrollers; 2. Implement a system for moving two or more controlled axes using interpolation algorithms based on the direct search method; 3. Physically realize the task of multi-axis movement defined in G-code on a microcontroller platform with interpolation algorithms based on direct search methods; 4. Generate a program for the movement of anthropomorphic robots and achieve their integration with the sensor environment by including real-time signal processing; 5. Conceptualize a system for computer monitoring of the manufacturing process. |
| 3.5 | hydropower engineering | 1423 | elective   | <b>Pumps and fans</b>                                              | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.                                       | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                                                                                                                                                                     |
| 4.1 | production engineering | 1195 | obligatory | <b>Skill Praxis M - PRO</b>                                        | The student gains practical experience and gets familiarized with the future occupational environment. The student                                                                                                                                                                                                | Upon successful completion of this course students should be able to:<br>(1) Apply practical experience on the organization                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

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|     |   |      |            | 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. | <p>and functioning of the business environment in which they will apply the acquired knowledge in their future professional career.</p> <p>(2) Students can identify the models of communication with the colleagues and business information flow.</p> <p>(3) Solve basic processes in the design, manufacturing, maintenance within the context of their future competences.</p> <p>(4) Establish of contacts and acquaintances are useful during graduate studies as well as for applying for the job in the future.</p> <p>(5) Prepare by Report professional practice upon on the completed tasks in given topics.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                                                                                                                                                                     | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and</li> </ul> |

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|     |   |      |            |                     | interpret the results and draw appropriate conclusions;<br><ul style="list-style-type: none"> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                             |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Railway Mechanical Engineering

| position | department                           | ID   |            | title                     | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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| 1.1      | railway<br>mechanical<br>engineering | 1186 | obligatory | <b>Rail vehicles 1</b>    | 1. Understanding of different constructions of the freight wagons and passenger coaches<br>2. Acquiring the knowledge necessary to understand the functioning of wagon or coach assemblies<br>3. Application of knowledge in the design, development, repair and maintenance of wagons and coaches                                                                                                                                                                                                                                                                  | After completion of the course the student should be able to:<br>1. Explain the functional and structural characteristics of various types of rolling stock.<br>2. Explain the tasks and functioning principles of the assemblies of the rail vehicles.<br>3. Identify actions required to resolve failures in operation and maintenance of rail vehicles.<br>4. Apply appropriate regulations and standards for design and maintenance of railway vehicles.<br>5. Apply computer tools for calculating and designing rail vehicles.                                                                                                                       |
| 1.2      | railway<br>mechanical<br>engineering | 1187 | obligatory | <b>Theory of Traction</b> | Knowledge acquiring in designing, production and exploitation of railway vehicle, in designing of rail tracks as well as the organization of railway traffic.<br>Introducing students with:<br>- The Forces acting on railway vehicle,<br>- Calculation methods for traction, resistance and braking force and the velocity, using modern computer tools,<br>- The methods for determination of optimal movement conditions of railway vehicles,<br>- Ways of solving practical problems related to the movement of railway vehicles and rail tracks configuration. | After successfully finishing of course students would be able to:<br>- define tasks and way of functioning elements, subassemblies and assemblies of tractive vehicles;<br>- calculate tractive effort, train resistance, braking force and velocity of railway vehicle using special software package;<br>- discuss about advantages and disadvantages of the different types of power transmissions and their characteristics;<br>- assessment of advantages and disadvantages of different types of coupling which can be used in tractive railway vehicles;<br>- implementation of regulations and standards in the field of railway vehicle traction. |

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| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Reza theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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.</p>                                                                                                                                                    |

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| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p>                                                                                                                                                                                 | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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| 1.5 | internal combustion engines                                        | 1435 | elective | <b>Internal Combustion Engines Fundamentals</b> | The course provides a comprehensive insight into the matter of the internal combustion (IC) engines (theoretical cycles, actual process, engine systems, operating characteristics). It is intended for students at the Department for IC engines, as an introduction to a deeper study of specific areas of internal combustion engines, as well as students of those fields where knowledge of IC engines as a propulsion unit (motor vehicles, shipbuilding, railway engineering, mechanization) is necessary. | Adopted theoretical and practical knowledge in the field of engines. Connecting fundamental disciplines: thermodynamics, fluid mechanics, mechanics, material resistance, etc. on a complex object such as the internal combustion engine. Acquiring the skills for a competent approach in the selection, organization of operation and maintenance of engines. Acquiring a base for further study of specific problems, construction and design of engines.                                                                                                                                     |
| 1.5 | hydropower engineering                                             | 1423 | elective | <b>Pumps and fans</b>                           | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.                                                                                                                                                                                                                                       | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density. |
| 1.5 | engineering materials and welding, tribology, fuels and combustion | 0899 | elective | <b>Welding processes M</b>                      | The aim of this course is for students to become competent in the area of welding. This course is designed to provide information through theoretical lectures, computational classes and seminar papers, but also through welding workshop practice. They should also                                                                                                                                                                                                                                            | Upon the successful completion of the course, the students are able to:<br>-Detail the differences between welding processes according to their characteristics<br>-Detail the range of application, appropriate joint preparations and potential problems to be overcome                                                                                                                                                                                                                                                                                                                         |

develop appropriate academic skills needed for the profession and become informed with the specificity of each welding process and appropriate equipment.

- Understand fully the fundamental physics of an electric arc, including the main parameters influencing arc stability
- Explain fully the principles of welding processes including transfer modes and their applications
- Explain the purpose and working principle of each component of the equipment
- Identify the influence of welding parameters on weld quality
- Choose appropriate welding process, power source, parameters and filler material for particular applications and materials
- Predict potential hazards and define methods for safe handling of welding equipment

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| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b> | <p>Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;</li> <li>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;</li> <li>3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;</li> <li>4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.</li> </ol> <p>Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.</p> |
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Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

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| 2.1 | railway mechanical engineering | 1566 | obligatory | <b>Locomotive 1</b>            | <p>1. Introduction student to the basic concepts important for understanding the designing of diesel locomotives.</p> <p>2. Knowledge acquiring necessary for understanding the designing of diesel locomotives.</p> <p>3. Competence for use the knowledge acquired in solving practical problems in designing, use and maintenance of diesel locomotives.</p> | <p>After successfully finishing of course students would be able to:</p> <ul style="list-style-type: none"> <li>- define basic characteristics of diesel locomotives;</li> <li>- describe tasks and way of functioning of assemblies of diesel locomotive;</li> <li>- compare tractive characteristics of different types of power transmissions;</li> <li>- calculate the key parameters using special software package;</li> <li>- implementation of regulations and standards in field of diesel locomotives.</li> </ul>                                                                                            |
| 2.2 | railway mechanical engineering | 1188 | obligatory | <b>Rail vehicles 2</b>         | <p>1. Understanding different constructions of the freight wagons and passenger coaches</p> <p>2. Acquiring the knowledge necessary to understand the functioning of wagon or coach assemblies</p> <p>3. Application of knowledge in the design, development, repair and maintenance of wagons and coaches</p>                                                  | <p>After completion of the course the student should be able to:</p> <ol style="list-style-type: none"> <li>1. Explain the functional and structural characteristics of various types of rolling stock.</li> <li>2. Explain the tasks and functioning principles of the assemblies of the rail vehicles.</li> <li>3. Identify actions required to resolve failures in operation and maintenance of rail vehicles.</li> <li>4. Apply appropriate regulations and standards for design and maintenance of railway vehicles.</li> <li>5. Applicate computer tools for calculating and designing rail vehicles.</li> </ol> |
| 2.3 | railway mechanical engineering | 1189 | obligatory | <b>Brakes of rail vehicles</b> | <p>1. Introducing the brake system of railway vehicles.</p> <p>2. Acquiring the knowledge necessary to understand the functioning of rail vehicle brake system components.</p> <p>3. Training for the application of</p>                                                                                                                                        | <p>After completion of the course the student should be able to:</p> <ol style="list-style-type: none"> <li>1. Explain the functional and design characteristics of various types of brakes.</li> <li>2. Explain the tasks and functioning mode of brake system assemblies.</li> </ol>                                                                                                                                                                                                                                                                                                                                 |

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|     |                                                                    |      |          |                                                        | knowledge in the design, development, repair and maintenance of the brakes.                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <p>3. Identify actions required to be applied in case of malfunctions of the break system during operation and maintenance.</p> <p>4. Apply appropriate regulations and standards for design and maintenance of rail vehicle brakes.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 2.4 | engineering materials and welding, tribology, fuels and combustion | 0719 | elective | <b>Service Properties of Welded Joints</b>             | The aim of this course is for students to become competent in the area of the analysis the current state of metal during service as well as failure and fracture of welded joints. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing. | <p>Upon the successful completion of the course, students are able to:</p> <ul style="list-style-type: none"> <li>- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;</li> <li>- determine the potential causes of damage;</li> <li>- perceive the eventual possibilities for preventing the occurrence of damage;</li> <li>- define the testing programme for detecting damages in mechanical structures;</li> <li>- prescribe maintenance measures for preventing damage in mechanical structures;</li> <li>- relate the acquired knowledge to other fields, with practical applications.</li> </ul> |
| 2.4 | hydropower engineering                                             | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | 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                                                          | <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,</li> <li>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,</li> <li>3. Process and present the measurement results,</li> <li>4. Calculate the measurement uncertainty,</li> <li>5. Explain the calibration of velocity, pressure and</li> </ol>                                                                                               |

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|     |                        |      |          |                                          | their transformation into electrical quantities using sensors. Through specific measurements in the laboratory, students are introduced to the field of practical experimental methods.                                                                                                              | flow measuring devices,<br>6. Describe the types and characteristics of sensors.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 2.4 | industrial engineering | 0513 | elective | <b>Risk management in Terotechnology</b> | The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to apply production and maintenance systems based on risk management, due to knowledge in the identification, analysis, risk assessment and decision-making on the basis of those facts. | 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. |
| 2.4 | mechanics              | 0037 | elective | <b>Theory of Mechanical Vibrations</b>   | 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.                                                                                 | Upon successful completion of this course, students will be able to: <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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</li> </ul>                                                                                                                                                                                                                                                                                                                                                  |

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.

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| 2.5 | general machine design | 1572 | elective | <b>High speed machine design</b> | The goal of the course is to introduce the students to the design of specific parts and assemblies of the high speed machines. | Upon successful completion of this course, students should be able to deal with the engineering design of specific parts and assemblies for high speed machine systems. The design methodology implies teaching student to calculate and correctly select bearings, couplings, seals, gears and other machine elements for operation at high speed revolutions. In addition students will have basic knowledge in |
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the field of the design of housing, lubrication, balancing and testing of such systems.

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| 2.5 | strength of structures                              | 0721 | elective | <b>Basics of Composite Materials Mechanics</b>                | <p>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.</p> | <ol style="list-style-type: none"> <li>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.</li> <li>2. Students will learn how to perform stress – strain analysis of laminate composite materials.</li> <li>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.</li> <li>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.</li> </ol> |
| 2.5 | engineering materials and welding, tribology, fuels | 0720 | elective | <b>Quality assurance and quality control of welded joints</b> | <p>The aim of this course is for students to become competent in the area of quality assurance and quality control of welded joints and welded structures. They should</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <p>After fulfilling all the course requirements, as prescribed by the course plan, the student is capable of applying the acquired knowledge to:</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

and combustion

also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing.

- Explain the importance of quality assurance (QA) and quality management (QM) of welded structures.
- Describes and to distinguish between different types of welded joint defects/imperfections/cracks.
- Defines possible causes for certain types of welded joint defects/imperfection/cracks.
- Defines the quality control plan for welding joints and welded structures.
- Apply quality control plan, QA and QM in the case of different welded structures.
- Defines specification and qualification of welding procedures for metallic materials.
- Connect the acquired knowledge in this field with other areas and applies them in practice.

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| 3.1 | railway mechanical engineering | 1567 | obligatory | <b>Locomotive 2</b>                 | <p>1. Introduction student to the basic concepts important to understanding the the designing of diesel-electric and electric locomotives.</p> <p>2. Knowledge acquiring necessary for understanding the designing of diesel-electric and electric locomotives.</p> <p>3. Competence for use the knowledge acquired in solving practical problems in designing, use and maintenance of diesel-electric and electric locomotives.</p> | <p>After successfully finishing of course students would be able to:</p> <ul style="list-style-type: none"> <li>- define basic characteristics of diesel-electric and electric locomotives;</li> <li>- describe tasks and way of functioning of the main assemblies of diesel-electric and electric locomotives;</li> <li>- compare ways of functioning and control of electric drive motors for DC and AC power;</li> <li>- calculate the key tractive parameters using special software package;</li> <li>- implementation of regulations and standards in field of diesel-electric and electric locomotives.</li> </ul> |
| 3.2 | railway mechanical engineering | 1568 | obligatory | <b>Railway vehicles maintenance</b> | <p>Upon completion of the course the student should be able to:</p> <p>1. Explain the basic concepts related to</p>                                                                                                                                                                                                                                                                                                                  | <p>After successfully finishing of course students would be able to:</p> <ul style="list-style-type: none"> <li>- define basic terms which are important for</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

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|     |                                |      |            |                                              | <p>the reliability of rail vehicles.</p> <p>2. Explain the basic concepts related to the maintenance of rail vehicles.</p> <p>3. Explain the tasks and practices of the workshop for the maintenance of railway vehicles.</p> <p>4. Perform appropriate calculations related to maintenance of rail vehicles.</p> <p>5. Apply appropriate tools for computer calculations of electric and diesel electric locomotives.</p> | <p>understanding of reliability and maintenance of railway vehicles;</p> <ul style="list-style-type: none"> <li>- choose an appropriate approach to the maintenance of railway vehicles;</li> <li>- 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;</li> <li>- make detailed scheme of the maintenance workshop of railway vehicles by using modern PC tools;</li> <li>- discuss about possibilities of improving of the maintenance process using modern methods for monitoring of system failure.</li> </ul> |
| 3.3 | railway mechanical engineering | 1190 | obligatory | <b>Fundamentals of Rail Vehicle Dynamics</b> | <p>1. Acquiring knowledge about the dynamic behavior of rail vehicles.</p> <p>2. Exploring methods for studying the dynamic behavior of rail vehicles.</p> <p>3. Training for the application of knowledge in the design, development, repair and maintenance of railway vehicles.</p>                                                                                                                                     | <p>After completion of the course the student should be able to:</p> <ol style="list-style-type: none"> <li>1. Explain the characteristic phenomena of dynamic behaviour of rail vehicles.</li> <li>2. Apply computational methods for determining the main parameters of the dynamic behaviour of the rail vehicles.</li> <li>3. Participate in the preparation of the test procedures for tests of the dynamic behaviour and proper assesment of the test results.</li> <li>4. Apply appropriate regulations for design or refurbishment of rolling stock in order to achieve the prescribed dynamic behaviour.</li> </ol>                                                                |
| 3.4 | general machine design         | 1444 | elective   | <b>Technical regulations and standards</b>   | <p>Acquiring of the basic knowledge in the field of technical regulations and standards. Fully understanding the mutual correlation between international and</p>                                                                                                                                                                                                                                                          | <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

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|     |                        |      |          |                                             | national technical regulations. Full training for the project documentation making in terms of respect for the essential requirements relevant to technical regulations and standards.                                                                                                                                                          | <ul style="list-style-type: none"> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                |
| 3.4 | motor vehicles         | 1565 | elective | <b>Urban and special rail vehicles</b>      | <ol style="list-style-type: none"> <li>1. Understanding the specifics of urban rail vehicles</li> <li>2. Understanding the various types of special rail vehicles</li> <li>3. Qualification for the application of acquired knowledge in the design, development, repair and maintenance of urban rail vehicles and special vehicles</li> </ol> | <p>After completion of the course, the student should be able to:</p> <ol style="list-style-type: none"> <li>1. Explain the functional and design specificity of various types of urban rail vehicles</li> <li>2. Explain the tasks and functionality of various types of special rail vehicles</li> <li>3. Explain the specific technologies and technical requirements in combined transport</li> <li>4. Apply appropriate regulations and standards in the design and maintenance of urban rail vehicles and special rail vehicles</li> </ol>                                                                                                                                                                  |
| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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.                                                                               | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> </ul> |

|     |                                                                    |      |          |                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
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|     |                                                                    |      |          |                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <ul style="list-style-type: none"> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                           |
| 3.5 | engineering materials and welding, tribology, fuels and combustion | 0537 | elective | <b>Tribological systems</b> | <p>The student attending this course should:</p> <ul style="list-style-type: none"> <li>• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);</li> <li>• Master the calculation methods for tribological elements using the modern lubrication theories;</li> <li>• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.</li> </ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"> <li>• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;</li> <li>• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;</li> <li>• Propose the solutions for problems originate from the friction and wear process;</li> <li>• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;</li> <li>• Applies methods for the calculation of working and tribological characteristics of considered tribological system;</li> <li>• Select materials, lubricants and lubrication mode for the considered tribological systems.</li> </ul> |
| 3.5 | hydropower engineering                                             | 1423 | elective | <b>Pumps and fans</b>       | <p>Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid.</p>                                                                                                                                                                                                                                                                                                                                                                                                       | <p>Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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|     |                        |      |          |                                          | Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.                                                                                                                                                                                                                                                                                                                                                                                   | energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                              |
| 3.5 | industrial engineering | 1418 | elective | <b>Appraisal of Projects in IT field</b> | Understanding the importance of the process of planning, evaluating and evaluating projects in the field of information technology. Introduction to different methodological approaches for the analysis of IT / IS projects. Mastering sophisticated techniques of financial and economic analysis as well as standard techniques for managing IT / IS projects. Mastering techniques and routines for identifying and monetary quantification of difficult to detect costs and effects implied by the implementation of IT / IS projects. | After completing the course the student should: identify the project idea, prepare a database with all costs and effects of IT / IS projects, calculate criteria for selection of project alternatives, gain knowledge and routines for recognizing difficult costs and effects of IT / IS projects, organize networks project resource flow activities with the choice of optimal paths and minimum costs and assess the uncertainty and risk of IT / IS projects. |
| 3.5 | motor vehicles         | 0876 | elective | <b>Forensic Engineering</b>              | Student is enabled to apply forensic engineering methods, particularly in the area of motor vehicles, which comprises analyses and reconstruction of road accidents. Analogous methods will be applied in other fields of mechanical engineering, depending on the interest of students.                                                                                                                                                                                                                                                    | Upon successful completion of this course, students should be able to:<br>- explain the concept of forensics and forensic engineering, with respect to vehicles;<br>- define and analyze technical system failures, their causes and effects, with a special emphasis on the application in automotive field;<br>- identify and analyze the causes of traffic accidents in which vehicles participated, with elements of                                            |

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|     |                                |      |            |                               | investigation and reconstruction;<br>- analyze adequate technical solutions and conditions under which accidents might be avoided.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 4.1 | railway mechanical engineering | 1301 | obligatory | <b>Skill Praxis M - ZEM</b>   | <p>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.</p> <p>After successfully finishing of skill praxis students would be able to:</p> <ul style="list-style-type: none"> <li>- define and discuss about design processes, production and maintenance of railway vehicles;</li> <li>- implementation of acquired practical knowledge about way of organization and functioning of producers and maintenance workshop of railway vehicles in the future professional career;</li> <li>- recognize models of communication with colleagues and flows of business information;</li> <li>- evaluate of the importance of team approach in resolving of problems, improving of production processes and maintenance of railway vehicles.</li> </ul>                                                                                                                                                                                                                                                                                                                                                               |
| 4.3 | -                              | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> </ul> |

the results.

- Apply standard tests and measurements: conduct, analyse and interpret the results;
- Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;
- Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;
- Consider different solutions critically and self-critically;
- Apply the acquired knowledge in practice;
- Adapt to newly arising situations in practice.

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| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> | <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"><li>• Present the results of independent work in written form;</li><li>• Create documentation in accordance with technical standards;</li><li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li><li>• Communicate efficiently with the engineering community and society as a whole;</li></ul> |
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## Thermal Power Engineering

| position | department                | ID   |            | title                   | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
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| 1.1      | thermal power engineering | 0274 | obligatory | <b>Steam Turbines 1</b> | <ol style="list-style-type: none"> <li>1. The achievement of academic competence in the field of steam turbines and thermal power engineering.</li> <li>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).</li> <li>3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam turbines.</li> <li>4. The achievement of the techniques of process modeling.</li> <li>5. Mastering the methods of experimental work in thermal power engineering.</li> </ol> | <p>On completion of this programme, it is expected that student will be able to:</p> <ul style="list-style-type: none"> <li>• identify the thermodynamic cycle parameters affecting the quality of the installation and optimization of thermodynamic cycle steam turbine,</li> <li>• perform calculation of of the heat balance diagram, the steam expansion process in the turbine, the process in the condenser and feedwater heater,</li> <li>• determine the main thermodynamic parameters of steam power plant that define the quality of plant operation</li> <li>• 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,</li> <li>• 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</li> <li>• apply one-dimensional theory of compressible fluid flow in the one-dimensional turbine stage design,</li> <li>• identify and select stage between action and reaction type,</li> <li>• professional and accurately communicate using the terminology of the respective product areas.</li> </ul> |

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| 1.2 | thermal science engineering | 1116 | obligatory | <b>Power steam boiler 1</b> | <p>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.</p> | <p>After successfully completing the course, the students will be able to:</p> <ul style="list-style-type: none"> <li>• Calculate the material balance of the combustion process and the enthalpies of combustion products for solid fuels.</li> <li>• Choose the excess air and apply flue gases recirculation.</li> <li>• Get to know more about the structure of the irradiated and convective evaporator.</li> <li>• Acquainted with the main superheater types and temperature control systems of a superheated vapor.</li> <li>• Acquainted with the basic types of water heaters and air heaters.</li> <li>• Calculate the heat balance of the steam boiler and its heat surfaces.</li> </ul> |
| 1.3 | fluid mechanics             | 1290 | elective   | <b>Fluid Mechanics M</b>    | <p>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.</p>                                                                                            | <p>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.</p>            |
| 1.3 | mechanics                   | 0004 | elective   | <b>Mechanics M</b>          | <p>The aim of this course is that students</p>                                                                                                                                                                                                                                                                                                                                                                   | <p>Upon successful completion of this course, students</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

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.

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 Reza theorem.
- Solve problems related to the impact (collision) of a particle and rigid body.

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements. | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.                       |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | 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                                                                                      | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal</li> </ul> |

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|     |                           |      |          |                         | 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.        | gas model.<br><ul style="list-style-type: none"> <li>•Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>•Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>•Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>•Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>•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.</li> </ul> |
| 1.5 | hydropower engineering    | 1423 | elective | <b>Pumps and fans</b>   | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function. | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                                                                                              |
| 1.5 | thermal power engineering | 0345 | elective | <b>Nuclear Reactors</b> | The aims of the subject are acquiring academic knowledge about processes and equipment for nuclear energy utilization,                                                                                                                                                      | Students are able to design nuclear reactor core, determine the thermal and neutron characteristics of nuclear fuel, moderator and reactor coolant,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

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|     |                                    |      |          |                               | 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.                                                                                                                                       | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 1.5 | thermomechanics                    | 1375 | elective | <b>Heat and Mass Transfer</b> | Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering. Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer. | Upon successful completion of the course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.</li> <li>• Explain the heat transfer in semi-infinite bodies.</li> <li>• Perform the heat transfer calculation in semi-infinite bodies.</li> <li>• Apply numerical methods for solving the problems of unsteady heat conduction.</li> <li>• Apply the basic laws of radiation in the in the calculation of radiation of the gas mixture.</li> <li>• Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer.</li> </ul> |
| 1.5 | physics and electrical engineering | 0401 | elective | <b>Electric Machinery</b>     | Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet                                                                                                                                                                    | Upon successful completion of this course, students should be able to: <ol style="list-style-type: none"> <li>1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;</li> <li>2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;</li> </ol>                                                                                                                                                                                                                                                                                                                                         |

during the course different types of electric machines.

3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;  
4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.

Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.

Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

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| 2.1 | thermal power engineering | 0174 | obligatory | <b>Steam Turbines 2</b> | <p>1. The achievement of academic competence in the field of steam turbines and thermal power engineering.</p> <p>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).</p> <p>3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam turbines.</p> <p>4. The achievement of the techniques of process modeling.</p> <p>5. Mastering the methods of experimental work in thermal power engineering.</p> | <p>On completion of this programme, it is expected that student will be able to:</p> <ul style="list-style-type: none"> <li>• optimization calculation of the turbine stage and select dimensionless stage parameters;</li> <li>• selects the type of turbine cascade, construct airfoils and calculated the corresponding losses,</li> <li>• set up a concept of the turbine relating to number of cylinders and the number of flow</li> <li>• determine number of the turbine stages,</li> <li>• conduct a detailed calculation of a turbine stages determining the main dimensions of the steam turbine,</li> <li>• apply the theory of 3D flow for the turbine stages,</li> <li>• perform basic design of steam turbine based on the carried calculations,</li> <li>• knows the problems of operation and design of the last steam turbine stage,</li> <li>• analysis of the problems of strength of the</li> </ul> |
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|     |                           |      |            |                               | <p>various elements of steam turbines</p> <ul style="list-style-type: none"> <li>• analyze the main problems vibration structural elements of the steam turbine,</li> <li>• select the methods of regulating and analyze the operation of steam turbine at off design conditions.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 2.2 | thermal power engineering | 1546 | obligatory | <b>Thermal Power Plants 1</b> | <p>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 performances 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.</p> <p>On completion of this course, it is expected that student will be able to:</p> <ul style="list-style-type: none"> <li>• identify different technological subsystems within the thermal power plant,</li> <li>• projects technological scheme of thermal power plants with steam and gas turbines,</li> <li>• conduct techno-economic analysis of the operation of thermal power plants, calculate the production price electricity and determine the economic feasibility parameters,</li> <li>• calculate and optimize the condenser plant,</li> <li>• determine the necessary flow of cooling water,</li> <li>• perform calculation and optimization of feed water heater.</li> </ul> |
| 2.3 | thermal power engineering | 0300 | obligatory | <b>Gas Turbines</b>           | <p>1. The achievement of academic competence in the field of gas turbines and thermal power plant engineering.</p> <p>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).</p> <p>3. The acquisition of practical skills for design and optimization of gas and gas turbine cycle.</p> <p>4. Mastering the techniques of process</p> <p>1. Academic deep knowledge of the thermodynamic cycle and flows in gas turbines and gas turbine plants</p> <p>2. The development of critical thinking about energy use, fuel efficiency and environmental preservation</p> <p>3. The ability of calculate heat balance diagrams and main parameters of the gas turbine power plants.</p> <p>4. Ability to use computer technology for modeling and calculations</p>                                                                                                                                                                                                                                                                                                                                                             |

modeling.

|     |           |      |          |                                        |                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
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| 2.4 | mechanics | 0037 | elective | <b>Theory of Mechanical Vibrations</b> | <p>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.</p> | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"><li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li><li>•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).</li><li>•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).</li><li>•Calculate (analytical and numerical) quantities which characterize vibration processes: natural frequencies, amplitudes, phase angles, logarithmic decrements and modal matrix.</li><li>•Determine equations of motion in analytical form using software (Matlab...) for systems with large number of degrees of freedom.</li><li>•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.</li><li>•Numerically solve characteristic equation for various cases of boundary conditions and determine angular frequencies. Determine</li></ul> |
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|     |                           |      |          |                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | analytical solutions of appropriate partial differential equations in simpler cases initial and boundary conditions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2.4 | thermal power engineering | 1319 | elective | <b>Environmental Protection in Thermal Power Engineering</b> | 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.                                                                                                                                                                                                          | 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.                                                                                                                            |
| 2.4 | hydropower engineering    | 0926 | elective | <b>Mechanical engineering measurements and sensors</b>       | 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. | On successful completion of this course, students should be able to:<br>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,<br>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,<br>3. Process and present the measurement results,<br>4. Calculate the measurement uncertainty,<br>5. Explain the calibration of velocity, pressure and flow measuring devices,<br>6. Describe the types and characteristics of sensors. |

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| 2.4 | thermal science engineering | 1498 | elective | <b>Pipelines</b>     | Achieving competencies and academic skills as well as methods for their acquisition. Development of creative abilities and mastery of practical skills specific to performing the profession. The goals are concrete and achievable and fully in line with the established basic tasks and goals of the study program. | The student acquires subject-specific abilities that are the function of quality performance of professional activities: analysis, synthesis and prediction of solutions and consequences, thorough knowledge and understanding of the profession, connecting the basic knowledge from different fields and their application to solving specific problems, monitoring and applying novelties in profession, development of skills and dexterity in the use of knowledge.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2.5 | thermomechanics             | 1451 | elective | <b>Heat transfer</b> | Students should gain basic theoretical and professional knowledge and skills that will enable them to independently recognize and solve a moderately complex multidimensional stationary and transient heat transfer problems that faced by engineers of thermo-technique, thermo-energetic and processes engineering. | <p>After successful completion of this course students should be able to:</p> <ol style="list-style-type: none"> <li>1) describe and explain the physical essence and mechanisms and express the basic hypotheses and laws that describe the processes of heat transfer: steady and unsteady heat conduction, natural and forced heat convection with and without changing phase state (boiling and condensation) and heat radiation of gases and vapors,</li> <li>2) calculate the temperature field and heat flow in solid bodies, especially rods, ribs and ribbed surfaces on the basis knowledge of the boundary and initial conditions in case of steady heat conduction</li> <li>3) calculate the temperature field in simple geometric solid bodies in case of unsteady heat conduction with the change the aggregate state - the melting and solidification</li> <li>4) calculate the local and average values the coefficient of heat transfer, ie. heat flux in case free and forced convective heat transfer for fluid flows across, through and around solid bodies but without changing its phase state,</li> </ol> |

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|     |                             |      |          |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                  | <p>5) calculate the heat flux, mass flow and thickness of the layer of condensate in case convective heat transfer during condensation of steam on the vertical and inclined solid surface,</p> <p>6) calculate the heat flux, mass flow and thickness of the layer of condensate in forced flow condensation of steam on the vertical and inclined solid surface,</p> <p>7) calculate the radiation heat flux from semi-transparent absorbing gases on opaque gray surfaces and the radiation heat flux from semi-transparent absorbing gases with solid particles on opaque gray surfaces.</p> |
| 2.5 | thermal science engineering | 1119 | elective | <b>Power steam boilers 2</b>                 | <p>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.</p> | <p>After successfully completing the course, the students will be able to:</p> <ul style="list-style-type: none"> <li>• Perform a thermal calculation of the boiler heat surfaces.</li> <li>• Select the fuel bed combustion systems.</li> <li>• Choose the device for pulverized coal preparation.</li> <li>• Perform the air and flue gases aerodynamic calculations of the power plant steam boiler.</li> <li>• Acquainted with hydrodynamic principles of evaporator with natural and forced convection, water heater and superheater.</li> </ul>                                            |
| 2.5 | thermal power engineering   | 0325 | elective | <b>Two-Phase Flows with Phase Transition</b> | <p>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</p>                                                                                  | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                              |

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|     |                           |      |            |                               | energy plants.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 2.5 | fluid mechanics           | 1011 | elective   | <b>Gas Dynamics</b>           | <p>The student should:</p> <ol style="list-style-type: none"> <li>1. acquire basic theoretical knowledge in the field of gas dynamics;</li> <li>2. be trained to perform basic engineering calculations of compressible flows;</li> <li>3. become familiar with the basic procedures for experimental research in gas dynamics.</li> </ol>                                                                                                                                                                                                                 | <p>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.</p>                                                                 |
| 3.1 | thermal power engineering | 0105 | obligatory | <b>Energy Planning</b>        | <p>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.</p> | <p>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.</p>                                                                                                      |
| 3.2 | thermal power engineering | 1547 | obligatory | <b>Thermal Power Plants 2</b> | <p>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</p>                                                                                                                                                                                                         | <p>On completion of this course, it is expected that student will be able to:</p> <ul style="list-style-type: none"> <li>• make preliminary design of the thermal power plant with steam and gas turbines,</li> <li>• analyze and choose the location for the construction of thermal power plants,</li> <li>• choose the most suitable thermal power technology for a given type of use,</li> <li>• perform calculation of the working conditions and</li> </ul> |

program.

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 design conditions,
- calculate production price of electricity and heat in combined energy production and economic feasibility parameters determine.

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| 3.3 | thermal power engineering                           | 0129 | obligatory | <b>Steam generators</b> | 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. | 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. |
| 3.4 | engineering materials and welding, tribology, fuels | 0519 | elective   | <b>Tribology</b>        | The student attending this course should: <ul style="list-style-type: none"> <li>• Comprehend the significance of friction, wear and lubrication (tribology keywords) and the problems connected with it, the</li> </ul>                                                                                                                                                                                                                   | Based on the mastered knowledge the student is qualified to: <ul style="list-style-type: none"> <li>• Identifies and critically analyze the basic causes of energy and material dissipation in some mechanical</li> </ul>                                                                                                                                                                                                                                                      |

and combustion

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.

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.

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| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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. | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human</li> </ul> |
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|     |                                                                    |      |          |                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <p>resource management, risk management and procurement on the project,</p> <ul style="list-style-type: none"> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul>                                                                                                          |
| 3.4 | engineering materials and welding, tribology, fuels and combustion | 1146 | elective | <b>Ecology of combustion</b> | <p>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.</p> | <p>After successful finishing the course students should be able to:</p> <ul style="list-style-type: none"> <li>- recognize and use modern technologies of the combustion processes,</li> <li>- use techniques for reduction of emission of harmful and polluting combustion products,</li> <li>- apply the acquired knowledge in combustion in the industry and energy sectors,</li> <li>- work in research and development organizations.</li> </ul> |
| 3.4 | thermal power engineering                                          | 1548 | elective | <b>Steam Turbines 3</b>      | <p>Introduction to the concept of combined production of electricity and heat, as well as steam turbines for this type of application. Specific design of turbines for industrial processes and electricity generation. Operation of components and the entire plant at off-design regimes. Diagrams of regimes for combined power generation. Turbines for special purpose, utilization of waste heat.</p>                                                            | <p>On completion of this programme, it is expected that student will be able to select type of the steam turbine for combined production of power and heat (CHP), select operating parameters, perform thermodynamic calculation of backpressure turbine for combined production of power and heat in nominal and off-design mode, select organic Rankine cycle for use of waste heat.</p>                                                             |
| 3.5 | thermal power engineering                                          | 0336 | elective | <b>Turbocompressors</b>      | <p>1. The achievement of academic competence in the field of compressors and thermal power plant engineering.</p>                                                                                                                                                                                                                                                                                                                                                      | <p>On completion of this programme, it is expected that student will be able to:</p> <ul style="list-style-type: none"> <li>• perform design of a multistage axial compressor</li> </ul>                                                                                                                                                                                                                                                               |

|     |                           |      |          |                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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|     |                           |      |          |                                                                   | <p>2. Mastery of theoretical knowledge about how to transform mechanical work into internal energy of fluid by learning of thermodynamic processes and equipment.</p> <p>3. The acquisition of practical skills for design and optimization of turbocompressors.</p> <p>4. Mastering the techniques of process modeling.</p>                                                                               | <p>writing own program code,</p> <ul style="list-style-type: none"> <li>• select dimensionless parameters of compressor stages,</li> <li>• apply one-dimensional theory of the compressor stage, determine the main dimensions of the stage, calculate efficiency and the stage operating parameters,</li> <li>• apply the appropriate solutions of 3D flow and define 3D blade geometry of the compressor stage</li> <li>• select the type of aero profile, calculate the aerodynamic losses and deviation</li> <li>• define the meridian flow path of the entire machine</li> <li>• apply different control modes for the turbocompressor</li> <li>• analyse compressor behavior at off-design operating parameters.</li> </ul> |
| 3.5 | thermal power engineering | 1320 | elective | <b>Computer simulations of thermalhydraulic processes and CFD</b> | <p>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.</p> | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 3.5 | thermomechanics           | 0924 | elective | <b>Solar energy</b>                                               | <p>Achieving academic competences in the field of solar energy utilization. Acquiring theoretical and practical knowledge on converting solar into thermal energy, acquiring skill of modeling and simulation</p>                                                                                                                                                                                          | <p>Upon successful completion of this course students should be able to:</p> <ul style="list-style-type: none"> <li>• Explain the characteristics of solar radiation at a specific location;</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

of processes.

- Analyze energy transport in the elements of the solar thermal systems;
- Formulate the mass and energy balances for the elements of the solar system (for solar collectors, thermal energy storages, heat exchangers, pipelines);
- Determine representative energetic characteristics of appropriate elements of the system;
- Analyze and thermodynamically evaluate the operation of various solar thermal systems.

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| 3.5 | engineering materials and welding, tribology, fuels and combustion | 0537 | elective   | <b>Tribological systems</b> | <p>The student attending this course should:</p> <ul style="list-style-type: none"> <li>• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);</li> <li>• Master the calculation methods for tribological elements using the modern lubrication theories;</li> <li>• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.</li> </ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"> <li>• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;</li> <li>• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;</li> <li>• Propose the solutions for problems originate from the friction and wear process;</li> <li>• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;</li> <li>• Applies methods for the calculation of working and tribological characteristics of considered tribological system;</li> <li>• Select materials, lubricants and lubrication mode for the considered tribological systems.</li> </ul> |
| 4.1 | thermal power engineering                                          | 1500 | obligatory | <b>Skill Praxix M - TEN</b> | <p>The aim of this course is to introduce students to the process of design and</p>                                                                                                                                                                                                                                                                                                                                                                                                                                            | <p>The successful completion of course students are introduced to: the appropriate energy</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

|     |   |      |            |                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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|     |   |      |            | 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. | processes, major and minor technological systems, the spatial distribution of equipment, methods, process analysis, measurement of process parameters, facilities management systems, etc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 4.3 | - | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                                                                                                                                                                                                                                                                                                                                                                                       | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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.</p> <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> </ul> |

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|     |   |      |            |                     | <ul style="list-style-type: none"> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                        |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul> |

## Thermal Science Engineering

| position | department                  | ID   |            | title                                        | goal                                                                                                                                                                                                                                                                                                                                                                                                      | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|-----------------------------|------|------------|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.1      | thermal science engineering | 1052 | obligatory | <b>Steam Boilers elements and equipments</b> | 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. | After successfully completing the course, the students will be able to: <ul style="list-style-type: none"> <li>• Calculate the material balance of the combustion process of solid fuels.</li> <li>• Choose the excess air and calculate the enthalpies of combustion products.</li> <li>• Choose the system of temperature control of a superheated vapor.</li> <li>• Select the fuel bed combustion systems.</li> <li>• Perform the preliminary thermal boiler calculation.</li> <li>• Get to know more about the plant by visiting the thermal power plant.</li> </ul> |
| 1.2      | thermal science engineering | 1114 | obligatory | <b>Refrigeration Equipment</b>               | 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.                                                                                   | 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.                                                                                                                                                                                                                                                       |
| 1.3      | fluid mechanics             | 1290 | elective   | <b>Fluid Mechanics M</b>                     | 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                                                                                                                                                                        | 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                                                                                                                                                                                                                                                                                 |

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|     |                 |      |          |                         | enable student to develop further in other topics based on fluid mechanics.                                                                                                                                                                                                                                                                                                                                                    | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>      | 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. | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Reza theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b> | 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                                                                                                                                                                                               | Upon successful completion of this course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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.

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.

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>            | Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements. | Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution. |
| 1.5 | thermal science engineering       | 1256 | elective | <b>Central Heating Systems</b> | 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                                                                                                                                                   | 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                                                                                                  |

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|     |                        |      |          |                               | low pressure, air heating, panel heating, district heating, solar systems, mastering the methods for calculation of pipe network.                                                                                                                                                                                                                                                                                                                                              | solve concrete problems in the technique of heating.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 1.5 | hydropower engineering | 1423 | elective | <b>Pumps and fans</b>         | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.                                                                                                                                                                                                    | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                                                                                          |
| 1.5 | thermomechanics        | 1375 | elective | <b>Heat and Mass Transfer</b> | Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering. Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer. | Upon successful completion of the course, students should be able to: <ul style="list-style-type: none"> <li>• Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.</li> <li>• Explain the heat transfer in semi-infinite bodies.</li> <li>• Perform the heat transfer calculation in semi-infinite bodies.</li> <li>• Apply numerical methods for solving the problems of unsteady heat conduction.</li> <li>• Apply the basic laws of radiation in the calculation of radiation of the gas mixture.</li> <li>• Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer.</li> </ul> |

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| 2.1 | thermal science engineering | 1053 | obligatory | <b>Steam Boiler processing</b>       | 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. | After successfully completing the course, the students will be able to: <ul style="list-style-type: none"> <li>• Perform the thermal boiler calculation.</li> <li>• Calculate the heat balance of the mill drying process and chose the type and size of the mill.</li> <li>• Perform the air and flue gases aerodynamic calculations of the steam boiler and choose an appropriate fan.</li> <li>• Perform the strength calculation of basic elements of a steam boiler.</li> <li>• Acquire the process of corrosion and wear of heating surfaces, as well as their protection.</li> </ul> |
| 2.2 | thermal science engineering | 1117 | obligatory | <b>Refrigeration Systems</b>         | 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.                                                                                   | 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.                                                                                                                                                                                                                                                                         |
| 2.3 | thermal science engineering | 1257 | obligatory | <b>Air-conditioning Fundamentals</b> | 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.                                                                                                                       | Upon successful completion of the course, students should be able to: <ul style="list-style-type: none"> <li>• Understand influence of indoor thermal conditions on human thermal comfort</li> <li>• Identified the process of unsteady heat transfer through the building envelope and inside air conditioned space</li> <li>• Perform cooling load calculation for air conditioned buildings</li> <li>• Select the appropriate amount of air for airconditioning system</li> </ul>                                                                                                        |

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|     |                             |      |          |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>• Carry out the selection of air handling unit elements heaters, coolers, humidifiers)</li> <li>• Compare the characteristics of different systems for air filtration</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2.4 | thermal science engineering | 1498 | elective | <b>Pipelines</b>                                       | Achieving competencies and academic skills as well as methods for their acquisition. Development of creative abilities and mastery of practical skills specific to performing the profession. The goals are concrete and achievable and fully in line with the established basic tasks and goals of the study program.                                                                                                                                                                                                                                                                                                                                          | The student acquires subject-specific abilities that are the function of quality performance of professional activities: analysis, synthesis and prediction of solutions and consequences, thorough knowledge and understanding of the profession, connecting the basic knowledge from different fields and their application to solving specific problems, monitoring and applying novelties in profession, development of skills and dexterity in the use of knowledge.                                                                                                                                                                                                        |
| 2.4 | hydropower engineering      | 0926 | elective | <b>Mechanical engineering measurements and sensors</b> | 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. | <p>On successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,</li> <li>2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,</li> <li>3. Process and present the measurement results,</li> <li>4. Calculate the measurement uncertainty,</li> <li>5. Explain the calibration of velocity, pressure and flow measuring devices,</li> <li>6. Describe the types and characteristics of sensors.</li> </ol> |

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| 2.4 | engineering materials and welding, tribology, fuels and combustion | 0971 | elective | <b>Combustion M</b> | <p>The objective of the course is for the student to:</p> <p>acquire basic knowledge about the importance of the combustion process; understand the different definitions of the combustion process; understand the physical and chemical processes that take place during combustion; perceive the most important laws that apply to combustion processes; perceive the thermodynamic basics of the combustion process; understand the material and energy balance of the combustion process; understand the basics of chemical statics and kinetics of thermal processes; perceive the types of chemical reactions that occur in combustion processes; understand the rate of chemical reaction and the influencing parameters; understand the occurrence of chemical equilibrium, its importance in the analysis of the development of chemical reactions and influential parameters; understand the thermal effects of chemical reactions; perceive the thermochemical laws; perceive the physical and physical-chemical phenomena in the combustion process (fuel and oxidizer mixing mechanisms, adsorption and absorption, diffusion); acquire basic knowledge about modeling the combustion process; perceive the classification of the combustion process</p> | <p>After successfully passing the exam in this course, the student will be able to:</p> <p>calculate the material and heat balance of the combustion process; determine the types of chemical reactions important for the combustion process; define the most important kinetic parameters for the considered chemical reactions; determine the thermal effect of chemical reactions; perform an analysis of influencing parameters on the development of chemical reactions and kinetic parameters; perceive the methods of fuel ignition and the spread of the flame front; application of available flame stabilization techniques; master flame testing techniques; perform an analysis of the efficiency of the combustion process; make a choice of technology and devices for combustion with the aim of meeting the energy and environmental characteristics; know how to apply available combustion process models; perform a comparison and analysis of the combustion process based on experimental results and modeling results; carry out the determination of toxic components produced during combustion; choose the best technology for reducing the emission of toxic components; perform an analysis of the impact of the combustion process on the environment.</p> |
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according to different criteria; understand the processes of ignition, flame propagation and stabilization of the flame front; understand the phenomena and specifics of combustion of gaseous, liquid and solid fuels; review technologies and devices for combustion of gaseous, liquid and solid fuels; understand the formation of toxic components during the combustion process and ways to reduce air pollution.

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| 2.5 | fluid mechanics | 1011 | elective | <b>Gas Dynamics</b>  | <p>The student should:</p> <ol style="list-style-type: none"> <li>1. acquire basic theoretical knowledge in the field of gas dynamics;</li> <li>2. be trained to perform basic engineering calculations of compressible flows;</li> <li>3. become familiar with the basic procedures for experimental research in gas dynamics.</li> </ol> | <p>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.</p>                                                                                                                                                                                                                                                                              |
| 2.5 | thermomechanics | 1451 | elective | <b>Heat transfer</b> | <p>Students should gain basic theoretical and professional knowledge and skills that will enable them to independently recognize and solve a moderately complex multidimensional stationary and transient heat transfer problems that faced by engineers of thermo-technique, thermo-energetic and processes engineering.</p>              | <p>After successful completion of this course students should be able to:</p> <ol style="list-style-type: none"> <li>1) describe and explain the physical essence and mechanisms and express the basic hypotheses and laws that describe the processes of heat transfer: steady and unsteady heat conduction, natural and forced heat convection with and without changing phase state (boiling and condensation) and heat radiation of gases and vapors,</li> <li>2) calculate the temperature field and heat flow in solid bodies, especially rods, ribs and ribbed surfaces on the basis knowledge of the boundary and initial conditions in case of steady heat</li> </ol> |

conduction

3) calculate the temperature field in simple geometric solid bodies in case of unsteady heat conduction with the change the aggregate state - the melting and solidification

4) calculate the local and average values the coefficient of heat transfer, ie. heat flux in case free and forced convective heat transfer for fluid flows across, through and around solid bodies but without changing its phase state,

5) calculate the heat flux, mass flow and thickness of the layer of condensate in case convective heat transfer during condensation of steam on the vertical and inclined solid surface,

6) calculate the heat flux, mass flow and thickness of the layer of condensate in forced flow condensation of steam on the vertical and inclined solid surface,

7) calculate the radiation heat flux from semi-transparent absorbing gases on opaque gray surfaces and the radiation heat flux from semi-transparent absorbing gases with solid particles on opaque gray surfaces.

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| 2.5 | thermal power engineering | 1499 | elective | <b>Thermal Turbomachinery</b> | <p>1. The achievement of academic competence in the field of steam and gas turbines and thermal power engineering.</p> <p>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).</p> | <p>1. Academic deep knowledge of the thermodynamic cycle and flows in steam and gas turbines and turbine plants</p> <p>2. The development of critical thinking about energy use, fuel efficiency and environmental preservation</p> <p>3. The ability of calculate heat balance diagrams and main parameters of the steam and gas turbine</p> |
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|     |                             |      |            |                                             | <p>3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam and gas turbines.</p> <p>4. The achievement of the techniques of process modeling.</p> <p>5. Mastering the methods of experimental work in thermal power engineering.</p>                                                                                                                                                 | <p>power plants.</p> <p>4. Ability to use computer technology for modeling and calculations</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 3.1 | thermal science engineering | 1054 | obligatory | <b>Thermal Power Plants and Heat Plants</b> | <p>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.</p> | <p>After successfully completing the course, the students will be able to:</p> <ul style="list-style-type: none"> <li>• Acquire the essence of heat balance condensing thermal power plant.</li> <li>• Be familiar with the regenerative heating feedwater schemes.</li> <li>• Get to know about the water supply, transport fuels, slag and ash transport and flue gases depuration before its removal to the atmosphere.</li> <li>• Get to know more about the principles of determining the location and general plan for thermal power plants and heating plants.</li> <li>• Compare theoretical knowledge with plant derived from visiting a thermal power plant or heating plant.</li> </ul> |
| 3.2 | thermal science engineering | 1120 | obligatory | <b>Heat Pumps</b>                           | <p>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.</p>                                                                                   | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                         |

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| 3.3 | thermal science engineering                                        | 1258 | obligatory | <b>Air Conditioning Systems</b>      | 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.                                                                                                                                                                                                          | <p>Upon successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Select the appropriate elements for supply air inlet in the air-conditioned room in order to achieve optimal air distribution in space</li> <li>• Apply of different methods for the calculation of pressure drop in air ducts</li> <li>• Explain the basic features central air conditioning systems (all air and air to water systems)</li> <li>• Apply measures to increase energy efficiency of the air conditioning systems</li> <li>• Estimate of the advantages and disadvantages of different systems for ventilation and air conditioning</li> <li>• Apply their knowledge to solving practical problems in air conditioning development, design and installation</li> </ul> |
| 3.4 | engineering materials and welding, tribology, fuels and combustion | 1146 | elective   | <b>Ecology of combustion</b>         | 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. | <p>After successful finishing the course students should be able to:</p> <ul style="list-style-type: none"> <li>- recognize and use modern technologies of the combustion processes,</li> <li>- use techniques for reduction of emission of harmful and polluting combustion products,</li> <li>- apply the acquired knowledge in combustion in the industry and energy sectors,</li> <li>- work in research and development organizations.</li> </ul>                                                                                                                                                                                                                                                                                                                                                      |
| 3.4 | thermal science engineering                                        | 1254 | elective   | <b>Building energy certification</b> | Acquiring knowledge and skills in the field of energy certification of buildings - the concept of energy building certificate,                                                                                                                                                                                                                                                                                                                                  | Students acquire specific skills and knowledge in the field of energy certification of buildings; known methods for the calculation of indicators to                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

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|     |                                      |      |          |                                         | 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.                                                                                                                                                                                                               | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 3.4 | thermal science engineering          | 1259 | elective | <b>Energy Efficiency in Buildings M</b> | <ul style="list-style-type: none"> <li>• gathering knowledge and skills required for energy efficient building design;</li> <li>• understanding of basic principles and calculation methods for energy efficient building design;</li> <li>• presentation of the concept and advantages of energy efficient buildings, zero and near zero energy buildings (ZEB, nZEB);</li> <li>• general overview of the methodologies that are used for estimation of building energy use and energy efficiency;</li> <li>• analysis of different scenarios and measures for improving energy efficiency of buildings and lowering energy consumption, while maintaining comfort;</li> </ul> | <p>After successfully finished course, student should be capable to:</p> <ul style="list-style-type: none"> <li>• apply methodology for calculating energy use for heating and cooling of buildings and CO2 emissions;</li> <li>• define all parameters necessary for estimating energy efficiency of buildings;</li> <li>• understand importance and advantages of increasing energy efficiency in buildings;</li> <li>• understand and apply methodology for estimating energy performance of buildings, suggest different scenarios for improvements and measures for energy savings;</li> <li>• have and use knowledge on existing methodologies and software for building and HVAC system design and measures for energy savings;</li> <li>• apply strategies for energy savings;</li> </ul> |
| 3.5 | process and environmental protection | 1549 | elective | <b>Heat exchangers</b>                  | Analysis of heat transfer operations and apparatus and their role in modern industry. Getting to know the most                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Mastering the calculation procedures required for the analysis of heat transfer operations - creating a heat balance, determining the operating line and                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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|     | engineering            |      |          |                       | commonly used types of heat transfer apparatuses - their construction and calculation procedures.                                                                                                                                                                           | driving force. Mastering the calculation procedures required for sizing the most commonly used heat exchangers.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 3.5 | thermomechanics        | 0924 | elective | <b>Solar energy</b>   | Achieving academic competences in the field of solar energy utilization. Acquiring theoretical and practical knowledge on converting solar into thermal energy, acquiring skill of modeling and simulation of processes.                                                    | <p>Upon successful completion of this course students should be able to:</p> <ul style="list-style-type: none"> <li>• Explain the characteristics of solar radiation at a specific location;</li> <li>• Analyze energy transport in the elements of the solar thermal systems;</li> <li>• Formulate the mass and energy balances for the elements of the solar system (for solar collectors, thermal energy storages, heat exchangers, pipelines);</li> <li>• Determine representative energetic characteristics of appropriate elements of the system;</li> <li>• Analyze and thermodynamically evaluate the operation of various solar thermal systems.</li> </ul> |
| 3.5 | hydropower engineering | 1423 | elective | <b>Pumps and fans</b> | Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function. | Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.                                                                    |

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| 3.5 | control engineering         | 0656 | elective   | <b>Intelligent Buildings</b>  | To introduce students to the concept of intelligent buildings, technical systems in modern buildings and control systems technology and their integration.                                                                                                                                                                                       | 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.<br>Student is able to create ETS project and program KNX components.<br>Student is able to make application schematics of HVAC system, to define signal list and define quote of sensors, actuators and controllers.                                                                               |
| 4.1 | thermal science engineering | 1255 | obligatory | <b>Skill Praxis M - TTA</b>   | 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.                              | 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. |
| 4.3 | -                           | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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, | Upon the successful completion of M.Sc. Thesis Project, engineers should be able to: <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> </ul>                                                                                                                 |

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|     |   |      |            | 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. | <ul style="list-style-type: none"> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul> |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b>                                                                                                                                                                                                                                                                      | <p>The preparation of M.Sc. 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 thesis.</p> <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li> <li>• Communicate efficiently with the engineering community and society as a whole;</li> </ul>                                                                                                                                              |

## Weapon Systems

| position | department      | ID   |            | title                                                 | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------|-----------------|------|------------|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.1      | weapon systems  | 1136 | obligatory | <b>Physics of explosive processes</b>                 | 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.                                                                                                                                                                                                         | 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. |
| 1.2      | weapon systems  | 1084 | obligatory | <b>Flight Dynamics and Aerodynamic of Projectiles</b> | 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. | 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.   |
| 1.3      | fluid mechanics | 1290 | elective   | <b>Fluid Mechanics M</b>                              | Main goal is to learn student general principles of fluid mechanics and how to apply them in solving practical                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Student will gain knowledge on general principles in fluid mechanics and develop capabilities of analytical thinking. Firstly, knowledge on general                                                                                                                                                                                                                                                                        |

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.

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.

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| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>      | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |
| 1.4 | thermomechanics | 0202 | elective | <b>Thermodynamics M</b> | <p>Student should gain knowledge in thermodynamics and thermal devices and plants that are present in process</p>                                                                                                                                                                                                                                                                                                                     | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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|     |                                   |      |          |                                     | <p>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.</p> | <p>Second principle of thermodynamics to the closed and open thermodynamic systems.</p> <ul style="list-style-type: none"> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |
| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>                 | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.</p> <p>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p>                                                               | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 1.5 | motor vehicles                    | 1141 | elective | <b>Maintenance of Machinery and</b> | <p>Managing Machine and Equipment Maintenance as part of Asset</p>                                                                                                                                                                                                                                                                                                                                                              | <p>Upon this comprehensive one semester course, students will be able to:</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

## Equipment

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:

- 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 value realization from assets
- Recognize the value 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-up for success from the start
- Understand the role of the project manager, business analyst, and others in managing projects
- Develop an integrated project plan including realistic scope, schedules, budgets, and risks
- Learn how to effectively track and report on project progress

- 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

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| 1.5 | mathematics | 0354 | elective | <b>Probability and statistics</b> | Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling. | <p>Upon successful completion of this course, students should be able to:</p> <ol style="list-style-type: none"> <li>1) Calculate probability and conditional probability of random events.</li> <li>2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.</li> <li>3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.</li> <li>4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.</li> </ol> |
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|     |                       |      |          |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <p>5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.</p> <p>6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 1.5 | aerospace engineering | 1383 | elective | <b>Rocket Motors</b>          | 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.                                                                                                                                                         | <p>By mastering the curriculum a student gains specific skills:</p> <ul style="list-style-type: none"> <li>-knowledge and understanding of rocket motors</li> <li>-calculation of rocket motor performances</li> <li>-design of geometry of propellant grain of solid rocket motor</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 1.5 | thermomechanics       | 1375 | elective | <b>Heat and Mass Transfer</b> | Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering. Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer. | <p>Upon successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>•Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.</li> <li>•Explain the heat transfer in semi-infinite bodies.</li> <li>•Perform the heat transfer calculation in semi-infinite bodies.</li> <li>•Apply numerical methods for solving the problems of unsteady heat conduction.</li> <li>•Apply the basic laws of radiation in the in the calculation of radiation of the gas mixture.</li> <li>•Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer.</li> </ul> |

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| 2.1 | weapon systems | 1297 | obligatory | <b>Fire control systems</b> | <p>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.</p> | <p>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.</p> |
| 2.1 | weapon systems | 0689 | obligatory | <b>Missile Propulsion</b>   | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                          | <p>After successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>- define the performance parameters of rocket engines,</li> <li>- independently calculate the main structural parts of solid propellants rocket engines,</li> <li>- analyze all subsystems of liquid propellants rocket engines,</li> <li>- understand different concepts of the thrust vector control systems of a rocket,</li> <li>- apply the acquired knowledge in the field of experimental work on the tests of rocket engines.</li> </ul>                                                                                                                                                                     |

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| 2.2 | weapon systems | 1385 | obligatory | <b>Interior Ballistics</b>          | 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.                                                                                                                                             | Mastering the calculation of direct and indirect task of interior ballistics of various types of weapons, and the methodology of interior ballistic tests.                                                                                                                                                                                                                                                                                   |
| 2.2 | weapon systems | 1386 | obligatory | <b>Automatic Weapons</b>            | 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.       | 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.                                                 |
| 2.3 | weapon systems | 1138 | obligatory | <b>Projectile design</b>            | 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.                                          | 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.                                                                                                                                                                                           |
| 2.3 | weapon systems | 1085 | obligatory | <b>Missile guidance and control</b> | 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, | 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 |

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|     |                                    |      |          |                                        | stability, etc. The eigen frequencies.) and autopilot synthesis and guidance law for the method of proportional navigation.                                                                                                                                                                                                                                                                                        | the missile guidance system. It has a basic knowledge of verification and assessment of the quality of guidance system.                                                                                                                                                                                                                                                                                                                           |
| 2.4 | aerospace engineering              | 0950 | elective | <b>High Speed Aerodynamics</b>         | 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).                                                                                                | 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.                                                                                                                           |
| 2.4 | physics and electrical engineering | 1324 | elective | <b>Electronics</b>                     | Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design. | Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.                                |
| 2.4 | mechanics                          | 0037 | elective | <b>Theory of Mechanical Vibrations</b> | 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.                                                                                                                                                                                               | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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</li> </ul> |

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.

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| 2.4 | internal combustion engines | 1478 | elective | <b>Sensors and Computer Based Measurements</b> | 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 to the world of virtual instrumentation and graphical | 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 applications (LabVIEW virtual instruments) for measurement and automation of various mechanical engineering systems. Practical knowledge in computer-based measurements of |
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|     |                       |      |          |                      | programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in 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 development and testing. | fundamental engineering data. Supplied basic knowledge and practice in the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.                                                                                                                                                                                                                                                                                                              |
| 2.5 | fluid mechanics       | 1011 | elective | <b>Gas Dynamics</b>  | The student should:<br>1. acquire basic theoretical knowledge in the field of gas dynamics;<br>2. be trained to perform basic engineering calculations of compressible flows;<br>3. become familiar with the basic procedures for experimental research in gas dynamics.                                                                                | 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.                                                                                                            |
| 2.5 | aerospace engineering | 0311 | elective | <b>Avionics</b>      | 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.                                                                          | 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. |
| 2.5 | thermomechanics       | 1451 | elective | <b>Heat transfer</b> | Students should gain basic theoretical and professional knowledge and skills that will enable them to independently recognize and solve a moderately complex multidimensional stationary and transient                                                                                                                                                  | After successful completion of this course students should be able to:<br>1) describe and explain the physical essence and mechanisms and express the basic hypotheses and laws that describe the processes of heat transfer:                                                                                                                                                                                                                                                                         |

heat transfer problems that faced by engineers of thermo-technique, thermo-energetic and processes engineering.

steady and unsteady heat conduction, natural and forced heat convection with and without changing phase state (boiling and condensation) and heat radiation of gases and vapors,  
 2) calculate the temperature field and heat flow in solid bodies, especially rods, ribs and ribbed surfaces on the basis knowledge of the boundary and initial conditions in case of steady heat conduction  
 3) calculate the temperature field in simple geometric solid bodies in case of unsteady heat conduction with the change the aggregate state - the melting and solidification  
 4) calculate the local and average values the coefficient of heat transfer, ie. heat flux in case free and forced convective heat transfer for fluid flows across, through and around solid bodies but without changing its phase state,  
 5) calculate the heat flux, mass flow and thickness of the layer of condensate in case convective heat transfer during condensation of steam on the vertical and inclined solid surface,  
 6) calculate the heat flux, mass flow and thickness of the layer of condensate in forced flow condensation of steam on the vertical and inclined solid surface,  
 7) calculate the radiation heat flux from semi-transparent absorbing gases on opaque gray surfaces and the radiation heat flux from semi-transparent absorbing gases with solid particles on opaque gray surfaces.

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| 2.5 | industrial engineering | 1370 | elective | <b>Design of logistic and warehouse</b> | Achieving competency and academic skills in the process of industrial system design. | Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of |
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|     |                |      |            | <b>systems</b>                      | 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.                                                                                                                                                                                                                                                                                                                                                                      | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 3.1 | weapon systems | 1560 | obligatory | <b>Artillery Weapons Design</b>     | 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                                                                                                                                                                                                                                                                                                                                                  | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 3.2 | weapon systems | 1299 | obligatory | <b>Missile design and launchers</b> | 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 | 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 |

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|     |                |      |            |                                            | <p>and development.</p> <p>Goal of subject is to achieve student knowledge in two basic launcher equipment</p> <p>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.</p> <p>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.</p> | <p>sub systems. Also launcher and its equipment is integrative design system test for knowledge of missile system design and defense functions.</p> <p>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.</p> |
| 3.3 | weapon systems | 1561 | obligatory | <b>Optical Devices and Optoelectronics</b> | <p>The aim of the course is to enable students, future mechanical engineers specializing in military systems design, to acquire the necessary knowledge for cooperation with designers of complex optical and optoelectronic systems. After attending lectures and exercises, students should be able to set up and calculate basic optical systems.</p>                                                                                                                                                                                                                                                                                        | <p>The course enables students, future mechanical engineers specializing in military systems, to: - set up basic optical systems (lenses, working systems, oculars, Keplerian and Galilean telescope configurations); - calculate optical systems using modern optical design software.</p>                                                                |
| 3.3 | weapon systems | 0691 | obligatory | <b>Terminal Ballistics</b>                 | <p>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</p>                                                                                                                                                                                                                                                                                                                                                                                                                                   | <p>After successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>- define all types of projectiles/warheads action on targets,</li> <li>- calculate the main parameters of all types of</li> </ul>                                                                                                     |

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|     |                     |      |          |                                    | understand the key ideas about the projectile/target interaction and their use in projectile design as well as ballistic protection.                                                                                                                                                                                                                                                         | penetration processes,<br>- analyze the characteristics of blast effect,<br>- model the mechanisms of high-explosive projectiles fragmentation effect,<br>- apply the experimental methods for determination of projectile efficiency parameters,<br>- understand the functional composition and the fundamentals of fuze design.                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 3.4 | control engineering | 0657 | elective | <b>Intelligent Control Systems</b> | <ul style="list-style-type: none"> <li>• Introduction to methods for the analysis and design of intelligent control systems.</li> <li>• Gaining practical knowledge of several of the main techniques of intelligent control and an introduction to some promising research directions.</li> <li>• Use of the computer for simulation and evaluation intelligent control systems.</li> </ul> | <p>On successful completion of the course the students should be able to:</p> <ul style="list-style-type: none"> <li>• Understand of the functional operation of a variety of intelligent control techniques.</li> <li>• Understand of control-theoretic foundations.</li> <li>• Carry out synthesis and analysis of intelligent control systems based on combinations of various theories: simulation, neural networks, fuzzy systems, genetic algorithms, biologically inspired algorithms, etc.</li> <li>• Use of the computer for simulation and evaluation intelligent control systems through Matlab/Simulink software, as and practical realization of control algorithms on various control plants using programming software Matlab.</li> </ul> |
| 3.4 | weapon systems      | 1562 | elective | <b>Hybrid technical systems</b>    | Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system                                 | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)</li> <li>• plan and implement procedures for HTS integration</li> <li>• develop new design solutions for HTS elements</li> <li>• create a new product based on technical</li> </ul>                                                                                                                                                                                                                                                                                                                                             |

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|     |                                                                    |      |          |                                            | integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | requirements as part of a complex system or the system as a whole <ul style="list-style-type: none"> <li>• develop experimental procedures for verifying HTS elements</li> <li>• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 3.4 | engineering materials and welding, tribology, fuels and combustion | 0519 | elective | <b>Tribology</b>                           | <p>The student attending this course should:</p> <ul style="list-style-type: none"> <li>• 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;</li> <li>• 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;</li> <li>• Solve problems related to the prevention of wear and competently decide on techniques to improve tribological properties of materials and lubrication technologies.</li> </ul> | <p>Based on the mastered knowledge the student is qualified to:</p> <ul style="list-style-type: none"> <li>• Identifies and critically analyze the basic causes of energy and material dissipation in some mechanical system;</li> <li>• Recognize the dominant type of wear in some mechanical system and to propose appropriate measures for its reduction;</li> <li>• Choose the appropriate type of material for the basic tribological elements (plain bearings, roller bearings and gears);</li> <li>• Describes and distinguishes the most common surface modification and coating deposition methods;</li> <li>• Explain the influences of temperature and pressure on the value of the viscosity (lubricants rheology);</li> <li>• Describes and distinguishes the basic types and methods of lubrication with their characteristics.</li> </ul> |
| 3.4 | general machine design                                             | 1444 | elective | <b>Technical regulations and standards</b> | Acquiring of the 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                                                                                                                                                                                                                                                                                                                                                                                                     | <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

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|     |                       |      |          |                                  | requirements relevant to technical regulations and standards.                                                                                                                                                                                                                                                                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                             |
| 3.5 | aerospace engineering | 0645 | elective | <b>Aeroelasticity</b>            | <p>1. introduction to modern aeroelasticity problems and their analysis and practical methods to solving aeroelasticity problems in real aircraft structures</p> <p>2. introduction to experimental dynamic analysis of aircraft structures</p> <p>3. introduction to dynamics of thin walled structures</p>                                                                                                                                                                   | <p>After successful competition of the course students should be able to:</p> <ol style="list-style-type: none"> <li>1. Determine forms of oscillation of thin walled structure</li> <li>2. calculate the torsional divergence speed of lifting surface</li> <li>3. Calculate the command reversal speed ( ailerons ) on the wings</li> <li>4. Estimate flutter speed of the lifting surface using Teodorsen method</li> <li>5. Generate finite element models of lifting surfaces of the aircraft for static and dynamic aeroelastic analysis .</li> </ol>                                                   |
| 3.5 | aerospace engineering | 1082 | elective | <b>Aircraft armement systems</b> | <p>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.</p> | <p>By mastering of the course curriculum student obtains following subject - specific skills:</p> <ul style="list-style-type: none"> <li>- thorough knowledge and understanding of different types of aircraft weapons and their application</li> <li>- calculation of air weapons characteristics and possibility of their integration into the aircraft with the use of scientific methods and procedures</li> <li>- linking basic knowledge in mathematics, programming, mechanics and fluid mechanics and their application in design and calculation of aviation weapons and its integration;</li> </ul> |

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| 3.5 | weapon systems | 1388 | elective   | <b>Missile navigation, guidance and control algorithms</b> | <p>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.</p> | <p>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 sensors 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.</p> |
| 4.1 | weapon systems | 1475 | obligatory | <b>Skill Praxis M - SIN</b>                                | <p>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.</p>                                                                                                                                                                                                                                                                                                                                                                                         | <p>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.</p>                                                                                                                                                                                                                                                                                                          |
| 4.3 | -              | 1504 | obligatory | <b>Course of M.Sc. Thesis</b>                              | <p>Applying engineering knowledge, techniques and skills in order to identify,</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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|     |   |      |            | <p>formulate and solve the given engineering task; 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.</p> | <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> <li>• Apply standard tests and measurements: conduct, analyse and interpret the results;</li> <li>• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;</li> <li>• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;</li> <li>• Consider different solutions critically and self-critically;</li> <li>• Apply the acquired knowledge in practice;</li> <li>• Adapt to newly arising situations in practice.</li> </ul> |                                                                                                                                                                                                                                                                                                                                        |
| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <p>The preparation of M.Sc. 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 thesis.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <p>Upon the successful defense of the M.Sc. thesis, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Present the results of independent work in written form;</li> <li>• Create documentation in accordance with technical standards;</li> <li>• Publicly present the results of their independent</li> </ul> |

work and express their own views on the M.Sc. thesis topic;

- Communicate efficiently with the engineering community and society as a whole;
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## Welding and Welded Structures

| position | department                                                         | ID   |            | title                                          | goal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | learning outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
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| 1.1      | engineering materials and welding, tribology, fuels and combustion | 0892 | obligatory | <b>Engineering materials 3</b>                 | 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, thermal processing and processing by plastic deformation on the structure and properties of the material. This course enables possible collaborations with institutes, companies and factories that make and construct engineering materials and deal with their application. | Upon the successful completion of the course, students are able to:<br>- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;<br>- determine the potential causes of damage;<br>- perceive the eventual possibilities for preventing the occurrence of damage;<br>- define the testing programme for detecting damages in mechanical structures;<br>- prescribe maintenance measures for preventing damage in mechanical structures;<br>- relate the acquired knowledge to other fields, with practical applications.                                   |
| 1.1      | engineering materials and welding, tribology, fuels and combustion | 0893 | obligatory | <b>Fuel, Lubricants and Industrial Water 2</b> | 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.                                                              | Upon completion of this course students should be able to:<br>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.<br>2 Define basic characteristics of solid fuels: moisture content, mineral content, the volatile content, carbon residue content, heating value.<br>3 Define basic characteristics of liquid fuel: behavior at elevated temperatures, behavior of low temperatures, density, water content and mechanical impurities, volatility, viscosity, |

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|     |                                                                    |      |            |                                    | <p>resistance to detonation and inflammability.</p> <p>4 Define the role of lubricants in engineering and basic characteristics of them</p> <p>5 Define the role of water for industrial applications and the most important characteristic: hardness and acidity.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 1.2 | engineering materials and welding, tribology, fuels and combustion | 0898 | obligatory | <b>Design of Welded Structures</b> | <p>After having completed the course, along with the theory and practical classes (through problems and calculation exercises, 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.</p> <p>Upon the successful completion of the course, the students are able to:</p> <ul style="list-style-type: none"> <li>• Identify the loading types of welded structures</li> <li>• Analyze the stress state of the welded structure (also with the presence of complex loads)</li> <li>• Solve specific problems of calculating welded structures with both fillet and butt welded joints</li> <li>• 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</li> <li>• Solve problems in the calculation of fatigue loaded welded structures</li> <li>• Solve problems in the calculation of dynamically loaded (impact) welded structures</li> <li>• 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</li> <li>• Solve the implications that may arise in cases of poor design, or as a result of material structural damage</li> <li>• 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</li> </ul> |

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| 1.3 | fluid mechanics | 1290 | elective | <b>Fluid Mechanics M</b> | <p>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.</p>                                                                                                                 | <p>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.</p>                                                                                                                                                    |
| 1.3 | mechanics       | 0004 | elective | <b>Mechanics M</b>       | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.</li> <li>• Analyze the motion of variable mass particle.</li> <li>• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.</li> <li>• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.</li> <li>• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Reza theorem.</li> <li>• Solve problems related to the impact (collision) of a particle and rigid body.</li> </ul> |

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| 1.4 | theory of mechanisms and machines | 1150 | elective | <b>Mechatronics</b>     | <p>Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm.</p> <p>Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.</p>                                                                                                                                                                          | <p>Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1.4 | thermomechanics                   | 0202 | elective | <b>Thermodynamics M</b> | <p>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.</p> | <p>Upon successful completion of this course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.</li> <li>• Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.</li> <li>• Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.</li> <li>• Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.</li> <li>• Recognize and describe the exergy of the open and closed thermodynamic system.</li> <li>• Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.</li> <li>• 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.</li> </ul> |

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| 1.5 | engineering materials and welding, tribology, fuels and combustion | 0899 | elective | <b>Welding processes M</b>              | <p>The aim of this course is for students to become competent in the area of welding. This course is designed to provide information through theoretical lectures, computational classes and seminar papers, but also through welding workshop practice. They should also develop appropriate academic skills needed for the profession and become informed with the specificity of each welding process and appropriate equipment.</p> | <p>Upon the successful completion of the course, the students are able to:</p> <ul style="list-style-type: none"> <li>-Detail the differences between welding processes according to their characteristics</li> <li>-Detail the rang of application, appropriate joint preparations and potential problems to be overcome</li> <li>-Understand fully the fundamental physics of an electric arc, including the main parameters influencing arc stability</li> <li>-Explain fully the principles of welding processes including transfer modes and their applications</li> <li>-Explain the purpose and working principle of each component of the equipment</li> <li>-Identify the influence of welding parameters on weld quality</li> <li>-Choose appropriate welding process, power source, parameters and filler material for particular applications and materials</li> <li>-Predict potential hazards and define methods for safe handling of welding equipment</li> </ul> |
| 1.5 | fluid mechanics                                                    | 1558 | elective | <b>Transport of fluid through pipes</b> | <p>The goal of studying the subject is to learn and study important engineering problems related to the pipeline transport of fluids, and especially to the calculation methods 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, methods of pipe support and techno-economic analysis of pipeline transport.</p>    | <p>As a result of studying the subject, mastering theoretical assumptions, physical laws, approximations and calculation methods of one-dimensional fluid flows through special purpose pipelines, such as: water pipelines, hot water pipelines, oil pipelines, gas pipelines and steam pipelines. As a result of the course, practical knowledge is obtained to solve technical problems: water hammer in pipelines, corrosion of pipelines, thermal expansion of pipelines and ways of supporting pipes.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

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| 1.5 | thermomechanics                                                    | 1375 | elective   | <b>Heat and Mass Transfer</b> | <p>Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering. Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer.</p> | <p>Upon successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> <li>• Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.</li> <li>• Explain the heat transfer in semi-infinite bodies.</li> <li>• Perform the heat transfer calculation in semi-infinite bodies.</li> <li>• Apply numerical methods for solving the problems of unsteady heat conduction.</li> <li>• Apply the basic laws of radiation in the calculation of radiation of the gas mixture.</li> <li>• Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer.</li> </ul>                                                                                                                                                                           |
| 2.1 | engineering materials and welding, tribology, fuels and combustion | 0901 | obligatory | <b>Welding metallurgy</b>     | <p>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.</p>                                                                                                                                  | <p>Upon the successful completion of the course, the students are able to:</p> <ul style="list-style-type: none"> <li>• Understand the distribution of temperature in the material during welding, and the influence of heat input on metal solidification</li> <li>• 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</li> <li>• Understand the metallurgical aspects of various steel classes (carbon-, low alloyed, high alloyed, stainless), and select the proper welding technique and appropriate welding consumables</li> <li>• 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)</li> <li>• Understand the metallurgical aspects of the</li> </ul> |

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|     |                                                                    |      |            |                                                    | weldability of heterogeneous metals                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|     |                                                                    |      |            |                                                    | <ul style="list-style-type: none"> <li>• 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</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 2.2 | general machine design                                             | 1441 | obligatory | <b>Machine Design and Construction M</b>           | <p>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.</p> <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• Through the design stages they will be able to select the optimum variant design from technological and economic point of view - Techno-economic analysis,</li> <li>• Applying technical directives and regulations in the machine design and putting the product on the market,</li> <li>• Evaluate the operational capacity of pressed joints,</li> <li>• Resolves advanced problems with measuring chains,</li> <li>• Check capacity of thin and thick-walled pressure vessels from strength point of view,</li> <li>• Make a selection of welded joints in terms of mutual position of the parts to be joined,</li> <li>• To form and do the technical documentation of given mechanical construction.</li> </ul> |
| 2.3 | engineering materials and welding, tribology, fuels and combustion | 1446 | obligatory | <b>Fracture mechanics and structural integrity</b> | <p>The objectives of the course are that students, after completing theoretical classes in fracture mechanics, as well as maximum engagement in practical classes (through laboratory exercises, calculation tasks, seminar papers, etc.), become competent in the field of structural integrity and acquire appropriate</p> <p>By mastering the study program, provided by the curriculum, the student is able to solve specific problems of structural integrity, as well as to see the possible consequences that may occur in case of poor solutions. The student is also able to connect the acquired knowledge in this field with other areas and apply them in practice.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

academic skills. they also develop creative abilities and master the specific practical skills needed to practice the profession.

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| 2.4 | process and environmental protection engineering | 1123 | elective | <b>Processes and Equipment for water treatment</b> | <p>The aim of the course is to give students the academic skills and competencies to monitor the process as well as the selection and designing appliances and devices used for water treatment. Through the term paper students acquire creative ability and specific practical skills for performing tasks within their profession, process monitoring and design of process equipment.</p> | <p>After successful course attending students get ability for: analysis, synthesis and predicting solutions and consequences; developing of critic and self-critic judgment and approach; practical implementation of knowledge; professional ethic; connecting knowledge from different areas and their implementation; developing skills and abilities for knowledge implementation in adequate area.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 2.4 | mechanics                                        | 0037 | elective | <b>Theory of Mechanical Vibrations</b>             | <p>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.</p>                                                                                                                                                                   | <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> <li>•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.</li> <li>•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).</li> <li>•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).</li> <li>•Calculate (analytical and numerical) quantities which characterize vibration processes: natural</li> </ul> |

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|     |                                                                    |      |          |                                            | <p>frequencies, amplitudes, phase angles, logarithmic decrements and modal matrix.</p> <ul style="list-style-type: none"> <li>•Determine equations of motion in analytical form using software (Matlab...) for systems with large number of degrees of freedom.</li> <li>•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.</li> </ul><br><ul style="list-style-type: none"> <li>•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.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 2.4 | engineering materials and welding, tribology, fuels and combustion | 0719 | elective | <b>Service Properties of Welded Joints</b> | <p>The aim of this course is for students to become competent in the area of the analysis the current state of metal during service as well as failure and fracture of welded joints. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing.</p> <p>Upon the successful completion of the course, students are able to:</p> <ul style="list-style-type: none"> <li>- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;</li> <li>- determine the potential causes of damage;</li> <li>- perceive the eventual possibilities for preventing the occurrence of damage;</li> <li>- define the testing programme for detecting damages in mechanical structures;</li> <li>- prescribe maintenance measures for preventing damage in mechanical structures;</li> <li>- relate the acquired knowledge to other fields, with practical applications.</li> </ul> |
| 2.5 | thermal power                                                      | 0325 | elective | <b>Two-Phase Flows</b>                     | <p>The aim is acquiring academic knowledge</p> <p>The students are trained to perform computer</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

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|     | engineering                                                        |      |          | <b>with Phase Transition</b>                                  | 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.                                                                                                                                                                                                       | simulation and analyses of gas-liquid two-phase flows within design of energy plants, safety analyses, operating conditions diagnostics, defining of operating conditions, etc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 2.5 | fluid mechanics                                                    | 1011 | elective | <b>Gas Dynamics</b>                                           | The student should:<br>1. acquire basic theoretical knowledge in the field of gas dynamics;<br>2. be trained to perform basic engineering calculations of compressible flows;<br>3. become familiar with the basic procedures for experimental research in gas dynamics.                                                                                                                                                                                                                              | 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.                                                                                                                                                                                                                                                                                                                                                                                   |
| 2.5 | engineering materials and welding, tribology, fuels and combustion | 0720 | elective | <b>Quality assurance and quality control of welded joints</b> | The aim of this course is for students to become competent in the area of quality assurance and quality control of welded joints and welded structures. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing. | After fulfilling all the course requirements, as prescribed by the course plan, the student is capable of applying the acquired knowledge to:<br><br><ul style="list-style-type: none"> <li>• Explain the importance of quality assurance (QA) and quality management (QM) of welded structures.</li> <li>• Describes and to distinguish between different types of welded joint defects/imperfections/cracks.</li> <li>• Defines possible causes for certain types of welded joint defects/imperfection/cracks.</li> <li>• Defines the quality control plan for welding joints and welded structures.</li> <li>• Apply quality control plan, QA and QM in the case of different welded structures.</li> <li>• Defines specification and qualification of welding</li> </ul> |

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|     |                                                  |      |            |                                                                 | procedures for metallic materials.<br>• Connect the acquired knowledge in this field with other areas and applies them in practice.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 3.1 | process and environmental protection engineering | 0363 | obligatory | <b>Design, construction and operation of processing systems</b> | <p>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.</p> <p>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.</p>                                                                                                                                                                                                                                                                                                                                |
| 3.2 | general machine design                           | 1482 | obligatory | <b>Optimization and reliability of constructions</b>            | <p>Learning the fundamentals of numerical analysis and optimization. Learning the fundamentals of optimization. Students are taught how to formulate optimization problems and identify essential parts of the optimization process. Teaching students how to use optimization methods to optimize constructions. Basic understanding of the reliability of machine components and constructions. Understanding how to determine the reliability of basic and complicated systems. Improving teamwork abilities and linking information and ideas from many fields. Knowing the technical and</p> <p>The student will be able to: 1. Establish the optimization model of the machine system, identify the necessary variables, and describe the functional limitations and criteria for the appropriate optimization assignment after successfully completing the course.<br/>2. Conduct an analysis and simulation of the sensitivity of the established functional constraints to parameter changes.<br/>3. Suggest a procedure for decomposing large construction optimization models into less complex ones, and create a MATLAB application to do so.<br/>4. Use one-dimensional and multidimensional numerical methods in the MATLAB software programme.</p> |

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|     |                                                                    |      |            |                           | <p>economic significance of failure, as well as possessing the knowledge to analyze failure based on the established cause-manifestation categories.</p>                                                                                                                                                                                                                                                                                                              | <p>6. Use and create new optimization methods to identify the optimal sizes of complicated machine systems on your own or as part of a team.</p> <p>7. Describe the fundamental markers of reliability indicators;</p> <p>8. Use approximation approaches to calculate the basic reliability indicators of machine parts and structures.</p> <p>9. Use analytical methodologies to determine the fundamental reliability indicators of machine parts and structures.</p> <p>10. Determine the parameters of basic distributions using probability paper;</p> <p>11. Examines the effect of working and critical stress distribution on the safety and reliability of machine parts and structures.</p> <p>12. Assess the reliability of complicated systems with series, parallel, and combination element connections.</p> <p>13. Constructs machine parts and assemblies on the reliability basis.</p> |
| 3.3 | engineering materials and welding, tribology, fuels and combustion | 1445 | obligatory | <b>Welding technology</b> | <p>Understanding the basic principles of welding technology development as a prescribed flow of activities to be followed when making each welded joint in the structure. Introducing students to the techniques of material selection, preparation, thermal cycle of welding, methods of ensuring and controlling the quality of welding and possible subsequent activities, subsequent heat treatment. Understanding and making examples of welding technology.</p> | <p>By attending the course, the student masters the basic skills and principles for the development of welding technology for a specific case. Theoretical considerations, as well as computational examples allow the student to master all the necessary principles of welding technology needed to make different types of welded joints. Introducing students to the existing modern standards and recommendations in the field and developing a critical way of thinking about them.</p>                                                                                                                                                                                                                                                                                                                                                                                                            |

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|     |                        |      |          |                                             | Development of independent work by making and presenting selected seminar papers.                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 3.4 | industrial engineering | 1248 | elective | <b>Techno-economic analysis and project</b> | 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. | <p>Upon completion of the course syllabus students will be able to:</p> <ul style="list-style-type: none"> <li>• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,</li> <li>• Understand the concept of project management methodology and project management processes,</li> <li>• Apply techno-economic analysis tools and techniques for project rentability,</li> <li>• Develops a WBS structural diagram in order to define the scope of the project,</li> <li>• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,</li> <li>• Explains the importance of managing project costs,</li> <li>• Explain quality control methods and techniques,</li> <li>• Apply tools and techniques to support human resource management, risk management and procurement on the project,</li> <li>• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,</li> <li>• Apply adequate software in project management.</li> </ul> |
| 3.4 | general machine design | 1444 | elective | <b>Technical regulations and standards</b>  | Acquiring of the basic knowledge in the field of technical regulations and standards. Fully understanding the mutual correlation between international and                                                                                                        | <p>After the attended course, students gain knowledge about:</p> <ul style="list-style-type: none"> <li>• the content, significance and types of technical regulations and standards,</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

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|     |                                                                    |      |          |                                                 | national technical regulations. Full training for the project documentation making in terms of respect for the essential requirements relevant to technical regulations and standards.                                                                                                                                                                                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• technical legislation of EU directives,</li> <li>• conformity assessment procedures, notified bodies,</li> <li>• CE marking, market surveillance,</li> <li>• machine safety,</li> <li>• Risk assessment and national legislation on safety and health at work.</li> </ul>                                                                                                                                                                                                                                                                                                                                    |
| 3.4 | process and environmental protection engineering                   | 0511 | elective | <b>Combustible, technical and medical gases</b> | The aim of this course is to familiarize students with the fuel characteristics, technical and medical gases, and to acquire academic skills and competencies for selection and calculation of equipment of gas installations. Through this course student mastery specific practical skills for work in the design and calculation of pipelines and fittings, storage tanks and other equipment for gas. Through laboratory student acquire knowledge related to testing of equipment for gas.                         | Successful completion of the study program the student receives the following general skills: analysis, synthesis and forecasting solutions and consequences, and develop critical thinking and self-critical approach, application of knowledge in practice, professional ethics, linking knowledge from different fields and their applications, development of skill and dexterity in the use of knowledge in the field of distribution and transportation of natural gas storage and technical gases.                                                                                                                                             |
| 3.5 | engineering materials and welding, tribology, fuels and combustion | 0537 | elective | <b>Tribological systems</b>                     | The student attending this course should: <ul style="list-style-type: none"> <li>• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);</li> <li>• Master the calculation methods for tribological elements using the modern lubrication theories;</li> <li>• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.</li> </ul> | Based on the mastered knowledge the student is qualified to: <ul style="list-style-type: none"> <li>• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;</li> <li>• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;</li> <li>• Propose the solutions for problems originate from the friction and wear process;</li> <li>• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;</li> </ul> |

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|     |                                                                    |      |          |                                       |                                                                                                                                                                                                                                                                                       | <ul style="list-style-type: none"> <li>• Applies methods for the calculation of working and tribological characteristics of considered tribological system;</li> <li>• Select materials, lubricants and lubrication mode for the considered tribological systems.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 3.5 | engineering materials and welding, tribology, fuels and combustion | 1147 | elective | <b>Combustion appliances</b>          | The objective of this course is to provide students with general appliances that use combustion methods.                                                                                                                                                                              | To teach and enable students to understand general combustion appliances and use the knowledge in industrial and energy sectors.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 3.5 | fluid mechanics                                                    | 0940 | elective | <b>Microfluidics and Nanofluidics</b> | 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. | <p>Students are trained to:</p> <ul style="list-style-type: none"> <li>-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;</li> <li>-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;</li> <li>- calculate the velocity and pressure field for isothermal compressible gas flow in micro channels, pipes and bearings for the slip flow regime;</li> <li>- calculate the velocity, pressure and temperature field for non-isothermal compressible gas flow in micro channels, for the slip flow regime;</li> <li>-calculate the pressure and velocity field for electroosmotic flow in micro and nano channels and pipes;</li> <li>- applie the law of diffusion equation and obtained analytical solutions which enables determination the change of a substance concentration in the</li> </ul> |

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|     |                                                                    |      |            |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <p>micro channel with no fluid stream, as well as in the fluid stream;</p> <p>-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.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 4.1 | engineering materials and welding, tribology, fuels and combustion | 1447 | obligatory | <b>Skill praxis M - ZZK</b>   | <p>The goals of the course are that students, after completing theoretical classes, are maximally engaged in conducting practical professional classes. The goal is for students to become competent in the field of welding and acquire appropriate academic skills, as well as develop creative abilities and master the specific practical skills needed to perform the profession.</p>                                                                                                                                                                                                                                          | <p>By mastering the study program, provided by the curriculum, the student is able to solve specific problems from practice, as well as to see the possible consequences that may occur in case of poor practical solutions. The student is also able to connect the acquired knowledge from different fields and apply them in practice.</p>                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 4.3 | -                                                                  | 1504 | obligatory | <b>Course of M.Sc. Thesis</b> | <p>Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; 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</p> | <p>Upon the successful completion of M.Sc. Thesis Project, engineers should be able to:</p> <ul style="list-style-type: none"> <li>• Identify, formulate, analyse and solve complex engineering problems;</li> <li>• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;</li> <li>• Design a system, component or process and respond to specified needs;</li> <li>• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;</li> <li>• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;</li> </ul> |

the results.

- Apply standard tests and measurements: conduct, analyse and interpret the results;
- Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;
- Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;
- Consider different solutions critically and self-critically;
- Apply the acquired knowledge in practice;
- Adapt to newly arising situations in practice.

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| 4.4 | - | 1503 | obligatory | <b>M.Sc. Thesis</b> | The preparation of M.Sc. 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 thesis. | Upon the successful defense of the M.Sc. thesis, engineers should be able to: <ul style="list-style-type: none"><li>• Present the results of independent work in written form;</li><li>• Create documentation in accordance with technical standards;</li><li>• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;</li><li>• Communicate efficiently with the engineering community and society as a whole;</li></ul> |
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