LUBLIN UNIVERSITY OF TECHNOLOGY
OF TECHNOLOGY
MECHANICAL
ENGINEERING FACULTY

# LUBLIN UNIVERSITY OF TECHNOLOGY
# PL LUBLIN03

## FACULTY OF MECHANICAL ENGINEERING (FME)

# ERASMUS+ Courses Catalogue

## for the academic year 2026/27

**Prepared by the FME ERASMUS+ Teachers**

**Approved by:**

| DEPUTY DEAN FOR EDUCATION AND INTERNATIONAL COOPERATION | FME ERASMUS+ COORDINATOR |
|---|---|
| Marek BOROWIEC , PhD Eng. | Zofia SZMIT, PhD Eng. |

LUBLIN, March 2026

# Courses available at the Faculty of Mechanical Engineering

**2026/2027**

**REMARKS:**

1. In square brackets, the course code and availability are given.
   ❄ – available in winter, ☼ – available in spring
2. Duration of all courses is 1 semester.
3. Semester: winter and/or summer means that the same course repeats in the winter and summer semester. Otherwise in the indicated semester ONLY.
4. The applying student can select up to 32 ECTS (1 semester mobility) or up to 62 ECTS (whole year mobility).
5. Up to 33% of courses specified in the Learning Agreement (LA) can be subjects offered by the other faculties of the Lublin University of Technology. Simultaneously, the number of points that can be gained at the other faculties of LUT should not exceed 12.
6. Upon arrival, the student is entitled to change up to 33% of courses listed in his/her Learning Agreement (LA). The "During the mobility" form must be delivered to the Coordinator no later than 14 days after the organizational meeting.
7. When the number of students applying for a course is less than specified in the catalogue, the faculty will have the right to cancel the course. In this case, the student should amend his/her Learning Agreement.
8. Please pay attention to the preliminary requirements.

Last update: 2024-09-17

# 3D Software Engineering - M01 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: No additional requirements.

CONTENTS:
Lecture: Introduction in 3D Software Engineering, Rapid prototyping technology, 3D printing technology, SLA, FDM, SLS, Reserve engineering technology, 3D scanning technology.
Laboratory: Introduction in Catia v5 software environment, Sketch module (Rectangle, Circle, Spline, Ellipse, Profile, Mirror, Symetry etc.), Part Design Modelling (Pad, Pocket, Shaft, Groove operations, Hole, Edge Filet, Chamfer, Rib, Multi-section etc.), Assembly Design Modelling, DMU Kinematics, Generative Shape Design, 3D Printing – practice, 3D Scanning – practice, Processing of 3D scanning surfaces using Digitized Shape Editor module.

EFFECTS OF EDUCATION PROCESS:
Student will gain knowledge about: 3D Software Engineering, Rapid prototyping technology, 3D printing technology, SLA, FDM, SLS, Reserve engineering technology, 3D scanning technology. Student with no experience in CAD systems will learn Catia v5 modelling (Part Modelling, Assembly Modelling, DMU Kinematics, Drafting, Generative shape Design). He will be able to draw 3D parts on his own, and will be able to make drawings from 3D parts. In addition he will learn how to make simulation and analysis of movement in Catia v5 systems. Student will be able to use file from 3D scanning to make surface model in Generative Shape Design, Free Style and Digitized Shape Editor module. Student will learn how to change solid model to surfaces model and vice versa.

LITERATURE:
- Jaecheol Koh: CATIA V5 Design Fundamentals - 2nd Edition: A Step by Step Guide,
- Sham Tickoo: Catia V5-6r2015 for Engineers and Designers, 13ed,
  Tutorial Book: CATIA V5-6R2015 Basics: Sketcher Workbench, Part Modelling, Assembly Design, Drafting, Sheet Metal Design, and Surface Design.

TEACHING METHODS: Multimedia lecture, Computer laboratories – practical experiments in Catia v5.

ASSESSMENT METHODS: Project presentation from lecture, Practice exam from Catia v5.

TEACHER: **Paweł Magryta, PhD Eng.**, p.magryta@pollub.pl, Konrad Pietrykowski, PhD Eng., k.pietrykowski@pollub.pl

# Engineering Project - M02 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Project |
| NUMBER OF HOURS: Project 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Passing at least 4 semesters of engineering studies. |
| CONTENTS:<br>Engineering project is thought to cover a solution of a technical problem, important from the point of view of a student, in relation to his/her specific background and needs, in relation to studies at the university of origin. The project can be realized in cooperation with a tutor from the student's home institution.<br>Engineering project cannot be identified with a thesis (neither engineering, nor master), but can partially fulfil the respective requirements. |
| EFFECTS OF EDUCATION PROCESS:<br>Student after the course will be able to state an engineering problem and solve it, using contemporary methods for calculations, numerical modelling or experimental testing. |
| LITERATURE:<br>Literature on practical aspects of mechanical engineering. |
| TEACHING METHODS: Multimedia instruction, project (calculation, drawing etc.). |
| ASSESSMENT METHODS: Project: defence. |
| TEACHER: **Sylwester Samborski, PhD Eng**, s.samborski@pollub.pl, Jakub Rzeczkowski PhD Eng., j.rzeczkowski@pollub.pl, Aleksander Czajka MSc Eng., a.czajka@pollub.pl |

# Advanced Strength of Materials - M03 ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 15h + Project 30h | ECTS: 4 |
| SEMESTER: summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Knowledge of math and physics at advanced level; knowledge of strength of materials at intermediate level. |
| CONTENTS:<br>Buckling. Elastic energy calculation in structures. Energetical methods. Mechanics of thin-walled plates and shells. Classical Lamination Theory. Basics of fracture mechanics. Dynamical problems. |
| EFFECTS OF EDUCATION PROCESS:<br>Students should gain understanding of an advanced problems of materials. |
| LITERATURE:<br>• R.C. Hibbeler: Mechanics of Materials, Prentice Hall, 2011;<br>• J.N. Reddy: Mechanics of Laminated Composite Plates and Shells: Theory and Analysis, CRC Press, 2004. |
| TEACHING METHODS: Multimedia lecture + Preparation of projects under the teacher's guidance. |
| ASSESSMENT METHODS: Lecture: final exam; Project: defense |
| TEACHER: **Sylwester Samborski, PhD Eng.**, s.samborski@pollub.pl, Jakub Rzeczkowski PhD Eng., j.rzeczkowski@pollub.pl, Aleksander Czajka MSc Eng., a.czajka@pollub.pl |

# Measurement Systems – M04 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 15h + Laboratory 15h + Project 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Fundamental knowledge of mathematics, physics and computer science.

CONTENTS:
The concept of a measurement system, its characteristics and tasks; Configuration and structure of measurement systems; Classification of measurement systems; Signal processing; Static processing of measurement signals; Dynamic processing of measurement signals; Characteristics of measuring sensors; Computer measurement systems; The essence and application of coordinate measuring technique; Parameterization of basic geometric elements; Relationships between geometric elements; Algorithms for determining associated elements; Coordinate measuring machines; Measuring head assembly; Coordinate measuring machine software; Coordinate measuring optical scanners; New trends in coordinate metrology; Basics of experiment planning.

EFFECTS OF EDUCATION PROCESS:
Students know: the concept, structure, tasks, and classification of measurement systems; theory of signal processing; characteristics of measuring sensors; the principles of computer-based measurement systems; the essence of coordinate measuring techniques, including geometric element parameterization, relationships between geometric elements, and algorithms for determining associated elements; the construction, operation, and software of coordinate measuring machines; the fundamentals and stages of experiment planning. Students can: analyse and process measurement signals; select and apply measuring sensors and computer measurement systems for experimental tasks; use coordinate measuring machines and interpret measurement results; plan and conduct experiments.

LITERATURE:


- He L., Feng B. Fundamentals of Measurement and Signal Analysis, Springer, 2022;
- Hocken R.J., Pereira P.H. Coordinate Measuring Machines and Systems, Taylor & Francis Group, 2012;
- Koch A.W. Measurement and Sensor Systems. A Comprehensive Guide to Principles, Practical Issues and Applications, Springer, 2023;
- Mekid S. Metrology and Instrumentation: Practical Applications for Engineering and Manufacturing, John Wiley & Sons, 2021;
- Sładek J.A. Coordinate Metrology: Accuracy of Systems and Measurements, Springer, 2016.


TEACHING METHODS: Lecture – multimedia presentations; Laboratory – practical exercises and discussions; Project - practical exercises and discussions (computer work).

ASSESSMENT METHODS: Lecture – assessment of final exam; Laboratory – assessment of laboratory reports; Project – assessment of individual project.

TEACHER: **Magdalena Zawada-Michałowska, Ph.D. Eng.**, m.michalowska@pollub.pl, Jarosław Korpysa, Ph.D. Eng., j.korpysa@pollub.pl

# Fundamentals of Assembly Process - M05 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 15h + Project 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Machine technology – basics; basic understanding of engineering principles and computer literacy, familiarity with CAD software is beneficial (not mandatory).

CONTENTS:
(1) Basic terms of the assembly technological process; (2) Assembly methods; (3) Organisational systems of assembly technological processes; (4) Technologicality in the assembly process; (5) Separable joints; (6) Non-separable joints; (7) Flexible assembly system; (8) Automatic assembly technological process.

EFFECTS OF EDUCATION PROCESS:
Student knows: the types of assembly methods, the types of joints used in assembly constructions. Student can: analyse the assembly process, select the appropriate method of joining, and draw the simple conclusions from experiments. Student sights problem of assembly in various constructions.

LITERATURE:
- Assembly technology (different authors),
- Crowson, R. (2006). Assembly processes: finishing, packaging, and automation. CRC Press.
- Journals on-line.

TEACHING METHODS: Lecture with multimedia presentation, discussion based on the student's presentations; Project – group or individual project, task solving - Separable joints technology design, non-separable joints technology design, case study analysis - calculation of separable and non-separable joints.

ASSESSMENT METHODS: Lecture – the received a course with the mark; Project – the received a course with the mark based on partial marks from prepared projects, reports on performed exercises.

TEACHER: **Izabela Miturska-Barańska, PhD Eng.**, i.miturska@pollub.pl, Anna Rudawska, Prof. PhD Eng., a.rudawska@pollub.pl

# Biomaterials - M06 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 20h + Laboratory 10h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Materials engineering – basics; chemistry – basics. |
| CONTENTS:<br>Metallic biomaterials – steels, cobalt alloys, titanium and its alloys, shape memory alloys, noble metals matrix alloys. Monolithic bioceramic and ceramics layers – properties, methods of testing, applications. Composites biomaterials and their applications. Long term biopolymers to the implantation. Conditions of materials admissibility in medicine – biocompatibility, the criteria, standards, testing methods etc. |
| EFFECTS OF EDUCATION PROCESS:<br>Student knows: the types of biomaterial, describe the properties and applications of biomaterials. Student can: analyse the special properties of biomaterials, select the appropriate material, draw the simple conclusions from experiments. Student understands social role of engineer intervention to alive organism. |
| LITERATURE:<br>• Encyclopedia of Materials: Science and Technology, Elsevier Ltd., 2007 (on line at LUT),<br>• The Biomedical Engineering HandBook, Second Edition., Ed. Joseph D. Bronzino, Boca Raton: CRC Press LLC, 2000,<br>• Brunette D. M., Tengvall P.i wsp., Titanium in Medicine, Springer Verlag, Berlin, Heidelberg, New York, 2001,<br>• Journals on-line and papers ed. at LUT. |
| TEACHING METHODS: Multimedia lecture, discussion based on the student's presentations; Laboratory – practical experiments. |
| ASSESSMENT METHODS: The received a course with the mark based on partial marks from lecture and laboratory. |
| TEACHER: **Monika Ostapiuk, PhD Eng.**, m.ostapiuk@pollub.pl, Krzysztof Pałka, PhD Eng., k.palka@pollub.pl |

# Casting Technology - M07 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basic knowledge about physics, chemistry and general knowledge related to materials science. |
| CONTENTS:<br>Introduction to metallurgy, structure of metals and alloys. Physical metallurgy. Ferrous and nonferrous metallurgy. Principles of solidification, crystallization. The moulding material: properties, preparation and testing. The feeding of castings. Casting design. Melting and casting. Casting technology techniques. The manufacture of sand castings. Shell, investment and die casting processes. Further casting techniques. Continuous casting. Heat treatment of metal alloys and castings. Finishing operations. Defects in castings. Characterization of ferrous and nonferrous casting alloys. Quality control of castings. |
| EFFECTS OF EDUCATION PROCESS:<br>This course helps students develop and understand basic metallurgical and foundry technology principles. Students acquire knowledge covering forming properties of engineering materials (metal alloys), the processes involved in the production and shaping properties of engineering materials applied in casting technology likewise metals, metal alloys, metal matrix composites. |
| LITERATURE:<br>• On-line journals related to casting technology and metallurgy and available at Lublin University of Technology. |
| TEACHING METHODS: Combination of theory and practice, group work and reporting, individual project work and investigation. |
| ASSESSMENT METHODS: Final exam based on compiling theory or homework assignments; reports, test or project evaluation. |
| TEACHER: **Mirosław Szala, PhD Eng.**, m.szala@pollub.pl, Krzysztof Majerski, PhD Eng., k.majerski@pollub.pl |

# Introduction to CNC Programming - M09 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Laboratory |
| NUMBER OF HOURS: Laboratory 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of machining.

CONTENTS:

Overview of CNC technology: history of CNC machines, main features, construction details, axes and the coordinate system, overview of programmable functions, role of the CNC machines in the manufacturing system, milling and turning technology, basic concepts, NC Program: structure of a NC program, code formatting, program verification techniques. CNC machine operation: coordinate systems used in CNC machines (axes, directions), zero point register, program zero point, absolute and incremental coordinate systems, inch and metric modes, basic machining operations, tools, plan of operations., communication to the operator, optional stop, block skip, thread cutting, active lathe tools.

Part programming – documentation flow in a typical company, preparation for programming, program portability, tool path programming, offsets, tool programmable point, tool length, cutting speed, feed, interpolation, tool geometry and wear compensation, fixed cycles.

EFFECTS OF EDUCATION PROCESS:

Student will get acquainted with the role and operation of CNC machines in a manufacturing system, basic procedures and safety standards. Student will learn the basic CNC process including: writing a CNC program, running the program in a machine simulator.

LITERATURE:

- P. Smid, CNC Programming Handbook, Industrial Press Inc., ISBN: 0831131586, 2003

TEACHING METHODS: Laboratory exercises with computer simulation.

ASSESSMENT METHODS: Activity during the classes, project evaluation, final test

TEACHER: **Kamil Anasiewicz, PhD Eng.**, k.anasiewicz@pollub.pl, Jakub Matuszak, PhD Eng., j.matuszak@pollub.pl

# Combustion Engines and Hybrid Propulsion Systems – M10 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h +Project 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Knowledge of physics, mechanics, thermodynamics.

CONTENTS:

Ideal and real engine cycles. Engine geometry and kinematics: volume above the piston, valves cross-section area. Intake and exhaust phenomena: gas flow through restrictions, volumetric efficiency. Combustion processes: combustion in spark ignition engines, combustion in diesel engines, modelling of combustion using heat release model, the first law of thermodynamics. Fuels, including mineral and renewable. Mixture formation and combustion control. Exhaust emissions: mechanisms of toxic compounds formation in the combustion chamber. Heat exchange: empirical correlations for heat exchange, heat losses in combustion engines. Engine as energy converter: fuel conversion efficiency, energy balance. Engine performance and characteristics: torque, power and brake mean effective pressure, fuel consumption and efficiency. Engine testing on a test bench. Thermodynamic analysis of real in-cylinder processes. Advanced combustion systems: homogeneous charge compression ignition, reactivity controlled compression ignition. Hybrid electric propulsion systems – design, operation and properties.

EFFECTS OF EDUCATION PROCESS:

Knowledge of combustion engines processes and operation. Knowledge of hybrid propulsion architecture. Ability to model engine processes. Ability to perform engine testing.

LITERATURE:

- J.B. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill, 1988.

TEACHING METHODS: Multimedia lecture + laboratory experiments+ self-contained project consulted with the teacher.

ASSESSMENT METHODS: Lecture: final exam; project: discussion.

TEACHER: **Jacek Hunicz, Prof. PhD Eng.**, j.hunicz@pollub.pl

# Composite Materials – M11 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Materials engineering – basics; chemistry – basics.

CONTENTS:
Elementary knowledge. Definitions and classification of composites. Matrix and reinforcement. Structure and properties of composites. Metal and ceramic matrix composites. Polymer composites. Sandwich composites. Fibre Metal Laminates (FML). Intelligent composites. Nanocomposites. Mechanics of composites (selected problems). Progress in composite materials. Application of composites.

EFFECTS OF EDUCATION PROCESS:
Student knows: the types of composite materials, describe the properties and applications of composites. Student can: analyse the special properties of composites, select the appropriate material, draw the simple conclusions from experiments. Student understands role of new materials such as composites.

LITERATURE:
- Encyclopedia of Materials: Science and Technology, Elsevier Ltd., 2007 (on line at LUT)
- ScienceDirect and SpringerLink data bases (scientific journals) in Lublin University of Technology Library.
- ASM Handbook Vol.: 1,2,4-7,15,16,21.

TEACHING METHODS: Multimedia lecture, discussion based on the student's presentations; Laboratory – practical experiments.

ASSESSMENT METHODS: Lecture – the received a course with the mark; Laboratory – the received a course with the mark based on partial marks from tests and reports.

TEACHER: **Jarosław Bieniaś, PhD Eng.**, j.bienias@pollub.pl

# Corrosion – M12 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Materials engineering – basics; chemistry – basics.

CONTENTS:
Base of corrosion, Types of corrosion, Corrosion in different environments, Corrosion protection, Corrosion resisting materials.

EFFECTS OF EDUCATION PROCESS:
Student knows: the types of corrosion and environment, describe the relationship between environment and materials. Student can: analyse the degradation process of materials, select the appropriate protection method, draw the simple conclusions from experiments. Student sights problem of corrosion in natural environment.

LITERATURE:

- Davis, J. R. Corrosion : Understanding the Basics Materials Park, Ohio : ASM International. 2000;
- Talbot D., Talbot J., Corrosion Science and Technology, CRC 1998;
- R. Winston H. Uhlig, Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering2008;
- Journals on-line.

TEACHING METHODS: Multimedia lecture, discussion based on the student's presentations; Laboratory – practical experiments.

ASSESSMENT METHODS: Final exam. Partial marks from lecture and laboratory.

TEACHER: **Krzysztof Majerski, PhD Eng.**, k.majerski@pollub.pl

# Diagnostics of Vehicles – M13 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: No additional requirements.

CONTENTS:
Lecture: Introduction to combustion engine technology, Diesel engines, Gasoline engines, Injection systems, Sensors, Fuel systems, Electronic Control Unit, Electronic Engine Control, OBD On Board Diagnostic, Toxic Compounds Emissions, Emission control, Future cars.
Laboratory: Gasoline injection systems, Diesel engine test bench, Gasoline engine test bench, Wankel engine test bench, OBD On Board Diagnostic, Driver assistance systems: Rear-view camera with parking assistance, Traffic sign recognition (TSR) with pre-emptive speed control, LIDAR (Light Detecting and Ranging) System, Adaptive Cruise Control (ACC) with emergency brake function, ADAS Active Lane Assist.

EFFECTS OF EDUCATION PROCESS:
Students will gain the information about combustion engine technology, Diesel engines, Gasoline engines, diagnostics of vehicles and emission control. They will gain practice knowledge during laboratory classes about: Gasoline and Diesel injection systems, OBD and Driver assistance systems.

LITERATURE:
- John Heywood: Internal Combustion Engine Fundamentals,
- Lino Guzzella, Christopher H. Onder: Introduction to modeling and control of internal combustion engine systems,
- C. Baumgarten: Mixture formation in internal combustion engines,
- Kevin L. Hoag: Vehicular Engine Design, Powertrain
- Hermann Hiereth, Peter Prenninger: Charging the internal combustion engine, Powertrain

TEACHING METHODS: Multimedia lecture, practice during the laboratory classes.

ASSESSMENT METHODS: Exam from lecture, reports from laboratory (group or individual).

TEACHER: **Paweł Magryta, PhD Eng.**, p.magryta@pollub.pl, Grzegorz Barański, PhD Eng., g.baranski@pollub.pl, Łukasz Grabowski, PhD Eng., l.grabowski@pollub.pl

# Advanced Numerical Methods – M14 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of calculus; Basic MATLAB programming knowledge (not compulsory).

CONTENTS:
Basics of programming in MATLAB/Python, types of errors and error sources, Review of calculus; Numerical methods for nonlinear equations: Simple iteration methods, Newton-Raphson, bisection method, Regula falsi, Secant method, numerical methods for a nonlinear set of equations; Numerical solutions of Linear system of equations – Gauss Elimination with pivoting, Gauss-Jordan, LU Decomposition, Jacobi and Gauss-Seidel methods; Numerical integration of functions – Simpson's rules, Trapezoidal method, Gauss Quadrature formulae; Numerical Differentiation – Finite Difference Method- two-point, three-point, and five-point formulation for first and second derivatives; Numerical Solution of Ordinary Differential Equations – Euler's method, RK methods, multi-step methods; Interpolation and Curve fitting.

EFFECTS OF EDUCATION PROCESS:
Students will be able to: understand the need of numerical methods in research and engineering, solve for simple analytical solutions, obtain numerical solutions for linear and nonlinear equations/system of equations, perform numerical procedure for differentiation, Integration, and solution of ODEs; Prepare algorithm and program for implementing numerical procedure in MATLAB, plot functions, visualize the solution process, write data output.

LITERATURE:
- Amos Gilat and Vish Subramanian, Numerical Methods for Engineers and Scientists, John Wiley & Sons, Cleveland 2008.
- John H. Mathews, Kurtis D. Fink, Numerical Methods Using MATLAB, 4th Edition, Pearson Prentice Hall, 2004.

TEACHING METHODS: Combination of white-board teaching (75%) and presentations (25%); Live MATLAB programming and simulation sessions for interactive participation; Use of physical and virtual models as required.

ASSESSMENT METHODS: 2 quiz or 1 Mid-semester exam, End Semester/Final Exam, Home assignments, and/or course project.

TEACHER: **Jakub Skoczylas, PhD Eng.**, j.skoczylas@pollub.pl, Grzegorz Litak, Prof. PhD, g.litak@pollub.pl

# Introduction to Aviation – M15 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture |
| NUMBER OF HOURS: Lecture 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Non.

CONTENTS:

(1) Flight as a physical phenomenon (forces acting on the aircraft, lift generation and thrust forces, aircraft control); (2) Aircraft classification (basic aircraft classification under aviation regulations, types, classes and types of aircraft, examples of structures, development trends in aeronautical structures); (3) Aviation law (history of the evolution of aviation law, Chicago Convention, ICAO International Civil Aviation Organisation, EASA European Aviation Safety Agency, Polish law - laws and regulations); (4) Responsibility and safety in aviation (aviation certification, initial and continuing airworthiness of aeronautical equipment, type certificates, design organisations, manufacturing and operating organisations, occurrence reporting, liability of persons working in aviation); (5) Flight crew (licensed personnel, principles and scope of training, how to obtain a licence and a certificate of competency, ratings, continuation of ratings); (6) Organisation of civil aviation ( airspace zoning and division, aerodromes, aeronautical maps, radio communication in aviation, Civil Aviation Authority, Polish Air Navigation Services Agency, Commission for Aviation Accident Investigation, international organisations); (7) Fundamentals of flight planning (aviation meteorology: meteorological information and forecasts meteorological information and forecasts, consideration of weather in flight planning, routing, flight plan, flight reporting)

EFFECTS OF EDUCATION PROCESS:

Familiarisation with civil aviation issues in terms of law, technology and organisation; Familiarisation with aviation-related terms; Familiarisation with the principles of safety and responsibility in aviation.

LITERATURE:

- Aviation law and Regulations;
- Federal Aviation Administration „Aviation Maintenance Technician Handbook – General" FAA-H-8083-30A, 2018
- Federal Aviation Administration „Aviation Maintenance Technician Handbook – Airframe" FAA-H-8083-31, 2012

TEACHING METHODS: Lectures

ASSESSMENT METHODS: Exam

TEACHER: **Jacek Czarnigowski, PhD Eng.**, j.czarnigowski@pollub.pl

# Computer Aided Design of Cutting Tools – M17 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 15h + Project 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Industrial tools – basics

CONTENTS:
Introduction: Construction and geometry of industrial tools. Principles of cutting tools selection from manufacturers' catalogues. Rules for selecting the type of machining and tool materials depending on the process. Cutting technological parameters. Introduction to solid modelling in the Solid Edge environment. Fundamentals of design cutting edge using CAD systems. Strength and geometric calculations of cutting tools, Overview of CNC machining processes.

EFFECTS OF EDUCATION PROCESS:
Student knows: the types of special cutting tools, the types of tools materials,. Student can: design cutting tool with all the necessary components, to determine the profile of the cutting edge using CAD methods (Solid Edge)

LITERATURE:

- cutting tools (different authors) ;
- Journals on-line (for example: Matuszak, Jakub, and Marcin Barszcz. "Computer aided design of cutting tools." Advances in Science and Technology Research Journal 9.28 (2015)).

TEACHING METHODS: Multimedia lecture + self-contained computer project of cutting tool consulted with the teacher.

ASSESSMENT METHODS: Lecture: final exam/test, project: project evaluation.

TEACHER: **Jakub Matuszak, PhD Eng.**, j.matuszak@pollub.pl, Agnieszka Skoczylas, PhD Eng., a.skoczylas@pollub.pl, Krzysztof Ciecieląg PhD Eng., k.ciecielag@pollub.pl

# Sheet Metal Forming and Numerical Modelling – M18 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture |
| NUMBER OF HOURS: Lecture 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Non

CONTENTS:
Metal forming technologies with industrial applications (presentations), numerical modelling of metal forming processes by Finite Element Method (presentations and computer laboratories). Scope of subject: basics of sheet metal forming, problematic of stress, strain, strain rate, friction and materials for billets and tools; technologies of metal forming: drawing, extrusion technologies; process designing and numerical calculation of chosen technology with application of Deform3D FEM software.

EFFECTS OF EDUCATION PROCESS:
Knowledge of metal forming basics, theory and different metal forming technologies and basics of numerical modeling by Finite Element Method.

LITERATURE:
- Metal Forming Technology (different authors);
- FEM (different authors).

TEACHING METHODS: Presentations, computer laboratories and project.

ASSESSMENT METHODS: Presentations, computer laboratories and project.

TEACHER: **Jarosław Bartnicki, PhD Eng.**, j.bartnicki@pollub.pl, Tomasz Bulzak, PhD Eng., t.bulzak@pollub.pl

# Bulk Metal Forming and Numerical Modelling – M19 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture |
| NUMBER OF HOURS: Lecture 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Non |
| CONTENTS:<br>Metal forming technologies with industrial applications (presentations), numerical modelling of metal forming processes by Finite Element Method (presentations and computer laboratories). Scope of subject: basics of bulk metal forming, cold, worm and hot forming conditions, problematic of stress, strain, strain rate, friction and materials for billets and tools; technologies of metal forming: rolling, forging; casting technologies; process designing and numerical calculation of chosen technology with application of Deform3D FEM software. |
| EFFECTS OF EDUCATION PROCESS:<br>Knowledge of metal forming basics, theory and different metal forming technologies and basics of numerical modelling by Finite Element Method. |
| LITERATURE:<br>• Metal Forming Technology (different authors);<br>• FEM (different authors). |
| TEACHING METHODS: Presentations, computer laboratories and project. |
| ASSESSMENT METHODS: Oral exam or project presentations. |
| TEACHER: **JarosławBartnicki, PhD Eng.**, j.bartnicki@pollub.pl, Tomasz Bulzak, PhD Eng., t.bulzak@pollub.pl |

# Fluid Mechanics I – M20 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercises, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercises 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basic of analysis, partial and ordinary differential equations; physics – basic laws. |
| CONTENTS:<br>Basic mathematical notions. Characteristic properties of fluids. Mass forces, surface forces, pressure, Pascal's law. Static equilibrium state. Relative equilibrium state. Static fluid-surface interaction. Archimedes law, stability of flotation. Ideal fluid flows: the continuity equation, Euler equation of flow. The Bernoulli equation, applications. Characteristics of multi-dimensional viscous fluid flow. Navier-Stokes equation of flow. Steady frictional pipe flows. |
| EFFECTS OF EDUCATION PROCESS:<br>The student understands fundamental principles of fluid behaviour, including fluid properties, pressure, mass and surface forces, Pascal’s law, and hydrostatic equilibrium. The student knows Archimedes’ law and stability of flotation. They understand ideal fluid flow described by the continuity, Euler, and Bernoulli equations and their applications. The student also has basic knowledge of viscous flows, including the Navier–Stokes equations and steady frictional pipe flows, and can apply these principles to solve basic engineering problems. |
| LITERATURE:<br>• Introduction to fluid mechanics by Y. Nakayama and R. F. Boucher, Butterworth-Heinemann, Oxford/Elsevier 2000. |
| TEACHING METHODS: Lecture, computational tasks. |
| ASSESSMENT METHODS: 4 computational tasks + multi-choice test/exam of theory : lab practices report. |
| TEACHER: **Tomasz Łusiak, PhD Eng.**, t.lusiak@pollub.pl |

# Fluid Mechanics II – M21 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercises, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercises 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Mathematics – basic of analysis, partial and ordinary differential equations; physics – basic laws. |
| CONTENTS:<br>Similitude and dimensional analysis, Lift and drag, The cascade wind tunnel, Flow rate measurements with orifices and nozzles, Flow rate measurement with Prandtl probe, Turbulent flow velocity profile measurements, Dimensional analysis law of similarity, Linear and local pressure losses in pipe flows, Hagen-Poiseuille law applications. |
| EFFECTS OF EDUCATION PROCESS:<br>The student understands the principles of similitude and dimensional analysis and their application in engineering modeling. The student knows the concepts of lift and drag forces and the operation of devices such as the cascade wind tunnel. They understand methods of flow rate measurement using orifices, nozzles, and the Prandtl probe, as well as techniques for measuring turbulent flow velocity profiles. The student also understands linear and local pressure losses in pipe flows and applications of the Hagen–Poiseuille law in fluid flow analysis. |
| LITERATURE:<br>• Introduction to fluid mechanics by Y. Nakayama and R. F. Boucher, Butterworth-Heinemann, Oxford/Elsevier 2000 |
| TEACHING METHODS: Lecture, computational tasks. |
| ASSESSMENT METHODS: 4 computational tasks + multi-choice test/exam of theory : lab practices report. |
| TEACHER: **Tomasz Łusiak, PhD Eng.**, t.lusiak@pollub.pl |

# Fundamentals of Rapid Prototyping – M22 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Laboratory |
| NUMBER OF HOURS: Laboratory 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic understanding of engineering principles and computer literacy, familiarity with CAD software is beneficial (not mandatory).

CONTENTS:
(1) Introduction to Rapid Prototyping: historical overview, applications across industries; (2) Fundamentals of 3D Printing Technologies: SLA, FDM, SLS, DLP etc., comparison of different techniques: strengths and weaknesses; (3) Theory of 3D Scanning Technologies; (4) Operation of 3D scanners: Scanning techniques and best practices, generating accurate 3D models from scans; (5) Operating different types of 3D printers: Understanding printer settings and parameters, Post-processing techniques for printed objects, introduction to 3D Printing Software.

EFFECTS OF EDUCATION PROCESS:
Better understanding of rapid prototyping technology and practical ability to use a 3D scanner and 3D print planning.

LITERATURE:

- Um, Dugan. Solid Modelling and Applications: Rapid Prototyping, CAD and CAE Theory. Second edition., Springer Nature, 2018, https://doi.org/10.1007/978-3-319-74594-7;
- Gibson, Ian, et al. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. 2nd ed. 2015, Springer Nature, 2014, https://doi.org/10.1007/978-1-4939-2113-3, 3) Narayan, Roger. Rapid Prototyping of Biomaterials : Principles and Applications. Woodhead Pub., 2014.

TEACHING METHODS: Introduction presentation/lecture, hands-on demonstrations/practical laboratories, group or individual project.

ASSESSMENT METHODS: Mark for the presentation of the completed project.

TEACHER: **Jakub Szabelski, PhD Eng.**, j.szabelski@pollub.pl, Izabela Miturska – Barańska, PhD Eng., i.miturska@pollub.pl

# Fundamentals of Machinery Operation and Maintenance – M23 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 15h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: None. |
| CONTENTS:<br>Phases of the existence of a technical object. Types of activities in the process of using and maintenance. Operation and maintenance requirements placed on machines. The processes of degradation of machine parts. Failure and technical state of a technical object. Maintenance strategies. Reliability of a non-renewable and renewable elements. Legal requirements for placing of machinery on the market or putting into service. Preparation of instructions for machinery. Noise measurements. Experimental determination of basic operational parameters of a machine. Determination of basic reliability characteristics. |
| EFFECTS OF EDUCATION PROCESS:<br>Student has knowledge of the principles of maintenance of machines and equipment, and the impact of the maintenance strategy for durability and reliability. Student is able to determine the basic reliability indicators and formulate service requirements placed on machines. Student is aware of the impact of the maintenance strategy to system efficiency and proper maintenance for the safety of people and the environment. |
| LITERATURE:<br>• Koszałka G., Ignaciuk P., Hunicz J.: Issues of machine and device operation and maintenance. Lublin Univ. of Technology, 2015. |
| TEACHING METHODS: Lecture with the use of multimedia presentation. Practical exercises and discussions based on the student's reports. |
| ASSESSMENT METHODS: Lecture – written exam. Laboratory – reports. |
| TEACHER: **Grzegorz Koszałka, PhD Eng.**, g.koszalka@pollub.pl |

# General Mechanics I – M24 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercises, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercises 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Knowledge of math and physics at an advanced level.

CONTENTS:

Lectures and Classroom exercises: (1) Introduction to mechanics. Notations and units, vectors, Rectangular component of a vector. (2) Statics laws. Addition of vectors, the product and dot product of vectors. Particle and rigid body. (3) Newton's Laws. Coplanar concurrent forces system, resultant (equivalent) force of coplanar forces system. (4) Dry friction – Coulomb's model. (5) Coplanar concurrent forces system. Resultant force of 2D concurrent system. Conditions of equilibrium. (6) Moment of force. Couple of forces, resultant force of parallel system. (7) Coplanar forces system. Reduction of coplanar forces system to force and moment. Conditions of equilibrium. (8) Analysis of trusses. Analysis of joints and sections. (9) Rolling friction. Examples. (10) Spatial concurrent forces system. Resultant force of 3D system. Conditions of equilibrium. (11) Spatial forces system. Resultant force and moment of 3D system. Conditions of equilibrium. (12) Area moments of inertia. Rectilinear motion of particle. (13) Velocity and acceleration. (14) Kinetics of particle. Formulation of dynamics problems, rectilinear motion, D'Alembert's principle and inertia forces. (15) Practical application of particle kinetics.

Laboratory: (1) Introduction to mechanics in a laboratory. Measuring techniques, safety regulations, notations and units. (2) Determining the location of the center of mass. (3) Determination of friction coefficients. (4) Analysis of a coplanar forces system. (5) Determination of friction of tendons. (6) Experimental determination of the geometric moment of inertia. (7) The resultant of a system of parallel forces. (8) Determination of forces in truss members.

EFFECTS OF EDUCATION PROCESS:

Students should gain an intermediate abilities to identify and to solve basic problems of mechanics.

LITERATURE:

- Beer, Johnston, Mazurek, Kornwell: Vector Mechanics for Engineers; (b) Michael Spivak: Elementary Mechanics From a Mathematician's Viewpoint; (c) Giovanni Gallavotti: The Elements of Mechanics.

TEACHING METHODS: Classical and multimedia lectures + problem solving exercises under the teacher's guidance + self-contained problems consulted with the teacher.

ASSESSMENT METHODS: Lecture: final exam, classroom exercises: two written tests in a semester.

TEACHER: **Andrzej Weremczuk, PhD Eng.**, a.weremczuk@pollub.pl, Łukasz Kłoda PhD Eng., l.kloda@pollub.pl

# General Mechanics II – M25 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercises, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercises 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Knowledge of math and physics at an advanced level.

CONTENTS:

Lectures: (1) Kinematics of particles: velocity and acceleration in rectangular, cylindrical, spherical and normal and tangential coordinates. (2) Motion of particles: rectilinear motion, relative motion. (3) Kinetics of particles: Newton's law of motion. Equations of motion. (4) Mass moment of inertia. (5) Work. Impulse. Momentum. (6) Principle of work and energy, principle of impulse and momentum. (7) Angular momentum, angular impulse and momentum principle. (8) Kinetics of systems of particles. (9) Planar kinematics of rigid bodies: instantaneous centre of rotation. (10) Planar kinetics of rigid bodies. (11) Three dimensional kinematics of rigid bodies. (12) Three dimensional kinetics of rigid bodies. (13) Unbalanced rotors.

Laboratory: (1) Introduction to mechanics in a laboratory. Measuring techniques, safety regulations, notations and units. (2) Determination of mass moment of inertia with physical pendulum method. (3) Determination of mass moment of inertia with elastic rod method. (4) Determination of mass moment of inertia with trifilar suspension method. (5) Investigation of uniformly accelerated rotational motion. (6) Determination of a screw efficiency coefficient using the principle of conservation of energy. (7) Forced vibrations of a one degree of freedom system.

EFFECTS OF EDUCATION PROCESS:

Students should gain an intermediate abilities to identify and to solve general problems of mechanics. Students should gain an intermediate abilities to operate measuring tools and recognize the parts of the equipment that should be measured. Students will be able to use knowledge gained in the laboratory in any experiments involving mechanical problems.

LITERATURE:

- Beer, Johnston, Mazurek, Kornwell: Vector Mechanics for Engineers;
- Michael Spivak: Elementary Mechanics From a Mathematician's Viewpoint;
- Giovanni Gallavotti: The Elements of Mechanics;
- R.C. Hibbeler: Engineering Mechanics.

TEACHING METHODS: Classical and multimedia lectures + problem solving exercises under the teacher's guidance + self-contained problems consulted with the teacher.

ASSESSMENT METHODS: Lecture: final exam, classroom exercises: two written tests in a semester. : Laboratory exercises, discussions about the exercises, explanation of the mechanical phenomenon taken under consideration in particular exercises, 60% - laboratory reports.

TEACHER: **Zofia Szmit, PhD Eng.**, z.szmit@pollub.pl, Krzysztof Kecik, Prof. PhD Eng., k.kecik@pollub.pl

# Heat Transfer – M26 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercises |
| NUMBER OF HOURS: Lecture 30h + Classroom exercises 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Mathematics – basic of analysis, partial and ordinary differential equations; physics – basic laws

CONTENTS:
Introduction to heat transfer: Fourier law, Newton law, Stefan-Boltzmann law. General heat conduction equation, steady 1D conduction through flat and cylindrical walls. Multi-layered walls, overall heat transfer coefficient, critical diameter of insulation. Rectangular fins, extended surfaces.
Convection heat transfer: Similitude and dimensional analysis. Discussion of forced- and free-convection heat transfer formulae. Boiling heat transfer.
Condensation heat transfer. Heat exchangers. Equimolar counter diffusion. Evaporation process in the atmosphere. Analogy between heat and mass transfer. Define Reynold's, Nusselt and Prandtl numbers. Sherwood and Schmidt numbers.

EFFECTS OF EDUCATION PROCESS:
The student understands the fundamental mechanisms of heat transfer: conduction, convection, and radiation, described by Fourier's, Newton's, and Stefan–Boltzmann laws. The student knows the general heat conduction equation and can analyse steady one-dimensional conduction through flat, cylindrical, and multilayer walls, including insulation effects and extended surfaces. They understand convection processes, boiling and condensation, heat exchangers, and basic mass transfer phenomena. The student is familiar with similarity principles and key dimensionless numbers such as Reynolds, Nusselt, Prandtl, Sherwood, and Schmidt numbers.

LITERATURE:

- Heat Transfer handbook by Bejan A. and Kraus A. D., John Wiley & Sons, 2003;
- Hand of heat transfer by Rohsenow W. M., Hartnett J. P. And Cho Y.I., McGrew-Hill, 1998.

TEACHING METHODS: Lecture, computational tasks.

ASSESSMENT METHODS: 4 computational tasks + multi-choice test of theory : lab practices report.

TEACHER: **Tomasz Łusiak, PhD Eng.**, t.lusiak@pollub.pl

# Heat Treating of Metals and Alloys – M27 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h +Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Chemistry, physics, general materials engineering

CONTENTS:
Principles of heat treating. Normalizing and annealing of steel. Quenching and tempering of steels. Thermomechanical processing of steel. Diffusion methods of surface hardening of steels. Carburizing of steel. Nitriding of steel. Other diffusion methods. Equipment for heat treating. Control of process parameters and effects. Heat treating of cast irons. Heat treating of tool steel. Heat treating of other steels and superalloys. Heat treating of nonferrous alloys. Heat treating of precious metals and alloys.

EFFECTS OF EDUCATION PROCESS:
Identify, formulate and solve engineering problems connected to heat treatment; understand the need and contribution of knowledge to the development of modern technology and society

LITERATURE:

- International Journal of Heat and Mass Transfer (on-campus access);
- Haasen P. (ed.): Phase Transformations in Materials. Weinheim 1991. (FME library);
- Muller K.A.: Structural phase transitions. Springer 1981 (library),;
- ASM Handbook (online).

TEACHING METHODS: Combination of theory (lecture) and practice, group work and reporting, individual project work and investigation.

ASSESSMENT METHODS: Lectures - final exam. Laboratory – mark for report.

TEACHER: **Kazimierz Drozd, PhD Eng.**, k.drozd@pollub.pl

# Introduction to Statistics for Engineers – M29 ❄

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: winter | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: High school higher algebra. |
| CONTENTS:<br>Descriptive statistics; graphical and numerical representation of information; measures of location, dispersion, position, and dependence; exploratory data analysis. Elementary probability theory, discrete and continuous probability models. Inferential statistics, point and interval estimation, tests of statistical hypotheses. Inferences involving one or two populations, ANOVA, regression analysis, and chi-square tests; use of statistical computer packages (Statistica). |
| EFFECTS OF EDUCATION PROCESS:<br>(1) Understanding the main features of descriptive statistics; (2) Ability to analyse statistical data with relevant statistical methods; (3) Sharpened students' statistical intuition and abstract reasoning as well as their reasoning from numerical data. |
| LITERATURE:<br>• Douglas C. Montgomery, George C. Runger, "Applied Statistics and Probability for Engineers";<br>• Dharmaraja Selvamuthu, Dipayan Das, "Introduction to Probability, Statistical Methods, Design of Experiments and Statistical Quality Control";<br>• John S. Oakland, "Statistical Process Control";<br>• Douglas C. Montgomery, "Introduction to Statistical Quality Control". |
| TEACHING METHODS: Lectures and computational laboratory. |
| ASSESSMENT METHODS: Several problems will be given for each assignment, and a post-test will be given at the end of the course. |
| TEACHER: **Martyna Sedlmayr, MSc Eng.**, m.sedlmayr@pollub.pl |

# Machine Parts/Elements I – M30 ❄

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Project |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 30h + Project 30h | ECTS: 7 |
| SEMESTER: winter | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basic knowledge of mathematics and engineering drawing. |
| CONTENTS:<br>Lecture and exercise: Introduction to mechanical design; Properties of materials; Static stress; Design of permanent joints; Screws and fasteners; Design of keys and splines; Column buckling. Project: Screw jack – performing necessary calculations and making 3D model of the jack. |
| EFFECTS OF EDUCATION PROCESS:<br>Student understand the concept of machine design and know how to design permanent joints and springs. |
| LITERATURE:<br>• Mott R. L., Vavrek E. M., Wang J.: Machine elements in mechanical design. Pearson<br>• Budynas R., Nisbett K.: Shigley's Mechanical Engineering Design. Mcgraw-Hill Series in Mechanical Engineering.<br>• Collins J. A., Busby H., Staab G.: Mechanical design of machines elements and machines. John Wiley & Sons. |
| TEACHING METHODS: Presentation, solving examples on the blackboard and modelling in CAD software. |
| ASSESSMENT METHODS: Homework 10%; Solving problems in the class 10 %; Exam 80 %. |
| TEACHER: **Łukasz Jedliński, PhD Eng.**, l.jedlinski@pollub.pl, Jakub Gajewski, PhD Eng., j.gajewski@pollub.pl |

# Machine Parts/Elements II – M31☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Project |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 30h + Laboratory 30h | ECTS: 7 |
| SEMESTER: summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Finished course machine parts/elements 1. |
| CONTENTS:<br>Lecture and exercise: Varying stress; Fatigue; Design of shafts; Rolling bearings; Spur and helical gears, Mechanical spring, Clutches. Project: Gearbox – performing necessary calculations and making 3D model of the transmission. |
| EFFECTS OF EDUCATION PROCESS:<br>Student know how to design more complicated devices like gearbox. |
| LITERATURE:<br>• Mott R. L., Vavrek E. M., Wang J.: Machine elements in mechanical design. Pearson<br>• Budynas R., Nisbett K.: Shigley's Mechanical Engineering Design. Mcgraw-Hill Series in Mechanical Engineering.<br>• Collins J. A., Busby H., Staab G.: Mechanical design of machines elements and machines. John Wiley & Sons. |
| TEACHING METHODS: Presentation, solving examples on the blackboard and modelling in CAD software. |
| ASSESSMENT METHODS: Homework 10%; Solving problems in the class 10 %; Exam 80 %  Lectures - final exam. Laboratory – mark for report. |
| TEACHER: **Łukasz Jedliński, PhD Eng.**, l.jedlinski@pollub.pl,  Jakub Gajewski, PhD Eng., j.gajewski@pollub.pl |

# Materials Engineering – M32 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: General chemistry, general physics.

CONTENTS:
Atomic and molecular structures of materials. Mono and policrystals. Defects in materials. Diffusion. Mechanical properties of materials. Mechanisms of strengthening. Failure of engineering materials. Equilibrium phase diagrams. Phase transformations. Applications and processing of metals and alloys. Introduction to ceramic materials. Introduction to polymers. Introduction to composites. Other materials and properties.

EFFECTS OF EDUCATION PROCESS:
Use the principles from chemistry and physics in engineering applications; identify, formulate and solve engineering problems connected to materials selection; understand and contribute to the challenges of a rapidly changing society.

LITERATURE:

- Callister W., Rethwisch D.G.: Materials science and engineering (pp. 30, 81, 150). Wiley 2015 (FME library);
- Narayanaswami R.: Materials characterization. Singapore 2015 (FME library);
- Jemioło S., Lutomirska M.: Mechanics and materials. Warsaw 2013 (FME library);
- Pytel M.: The basic of material science. Cracow 2013;
- Czichos H., Tetsuya S., Leslie S.: Springer handbook of materials measurement methods. Berlin 2006 (FME library);
- Courtney T.H.: Mechanical behavior of materials. Boston 2000

TEACHING METHODS: Combination of theory (lecture) and practice, group work and reporting, individual project work and investigation.

ASSESSMENT METHODS: Lectures - final exam. Laboratory – mark for report.

TEACHER: **Kazimierz Drozd, PhD Eng.**, k.drozd@pollub.pl

# Materials Testing Methods – M34 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Basic knowledge of the science of materials, General knowledge of physics and chemistry; knowledge of fundamental physico-chemical properties of materials; engineering in practice.

CONTENTS:
Structure of the materials and the method of structural studies. Distribution of research methods of structure and properties. Macroscopic and microscopic observations of proper and failure of choosing engineering structure. NDT techniques (ultrasonic testing, x-ray tomography); Scanning electron microscopy (SEM); Scanning Tunneling Microscope (STM); Transmission electron microscopy (TEM); Atomic force microscopy (AFM); Computer tomography (CT); Electron probe X-ray Analysis X-ray spectrometer for chemical analysis; Micro- and nano hardness; Auger Electron Spectrometer (AES); Methods of non- destructive testing of corrosion – MFL, TOFD, PIT, MAPSCAN; X-ray Diffractometer; Applications of the synchrotron radiation for materials. Destructive testing materials (strength tests, preparation of the samples). Analysis about the phenomena of failure the structures.

EFFECTS OF EDUCATION PROCESS:
Student characterize the research methods used in materials engineering. Student distinguishes and describes the testing equipment. Student is able to plan research experiment for basic materials engineering.

LITERATURE:


- Freiman S.W., Mecholsky J.J.Jr.:" The Fracture of Brittle Materials. Testing and Analysis", John Wiley and Son, 2012;
- Cardarelli F.: "Materials Handbook", Spirnger, 2008;
- Kutz M.: "Handbook of Materials Selection", John Wiley and Son, 2002;
- Thorsten M. Buzug: Computed Tomography. Springer-Verlag Berlin Heidelberg, 2008;
- William N. Sharpe, Jr. (Editor): Handbook of Experimental Solid Mechanics. Springer Science+Business Media, LLC New York, 2008;
- Paul E. Mix: Introduction To Nondestructive Testing. John Wiley & Sons, Inc., Hoboken, New Jersey, 2005;
- C. H. Chen (Editor): Ultrasonic And Advanced Methods For Nondestructive Testing And Material Characterization. World Scientific Publishing Co. Pte. Ltd., 2007


TEACHING METHODS: Multimedia lecture, discussion based on the student's presentations; Laboratory – practical experiments and observations.

ASSESSMENT METHODS: The received a course with the mark based on partial marks from laboratory. Final exam.

TEACHER: **Monika Ostapiuk, PhD Eng., m.ostapiuk@pollub.pl**

# Mechanical Vibrations – M36 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h + Project 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Knowledge of mathematics of linear differential equations and partial differential equations.

CONTENTS:
(1) Introduction. Classification of vibrations, positive and negative effects of vibrations. Modelling of real systems, discrete and continuous systems. Equivalent stiffness of springs connected in parallel and series. (2) Free vibrations. Natural frequency, differential equation of motion of linear systems. Longitudinal, tensional and transverse vibration. (3) Damped vibrations. Differential equation of motion, frequency of damped vibration with viscous damping. (4) Forced vibration. Forced vibrations of linear systems with viscous damping. Mechanical resonance. (5) Free vibration of lumped mass systems with multi degrees of freedom. Differential equations of motion in matrix approach. Vibrations frequencies and modes in multi degrees of freedom systems. (6). Numerical approach in modelling of multi degrees of freedom systems (7) Forced oscillations of a two degree of freedom system. Resonance and anti-resonance effect. Dynamical vibration absorber. (8) Vibrations of continuous systems. Analysis of a string vibrations. (9) Transverse vibrations of beams. (10) Longitudinal and torsional vibrations of rods. CONTENTS of laboratories: (1) Introduction to mechanical vibrations in a laboratory. Measuring techniques, safety regulations, notations and units. (2) Natural oscillation investigation in an experiment with oscillating rigid beam. (3) Damped oscillation investigation in an experiment with oscillating rigid beam. (4) Forced vibrations of a one degree of freedom system. (5) Investigation of uniformly accelerated rotational motion. (6) Dynamic balancing of rotating elements. (7) Resonance investigation in a kinematically excited system. (8) Recording of resonance curves with damping.

EFFECTS OF EDUCATION PROCESS:
Students should gain an intermediate abilities to identify and to solve problems of mechanical vibrations.

LITERATURE:


- Meirovitch L., Fundamentals of Vibrations, McGraw-Hill international Ed., 2001;
- Rao S.R., Mechanical Vibrations, 5th Ed., Prentice Hall, 2004.


TEACHING METHODS: Classical and multimedia lectures + problem solving exercises under the teacher's guidance + self-contained problems consulted with the teacher. Laboratory exercises, discussions about the exercises, explanation of the mechanical phenomenon taken under consideration in particular tests.

ASSESSMENT METHODS: Lecture: final exam, project: reporting the problem and delivering final reports of solution, laboratory: 60% - laboratory reports, 40% short tests before every laboratory exercise.

TEACHER: **Łukasz Kłoda, PhD Eng.**, l.kloda@pollub.pl, Marek Borowiec, PhD. Eng, m.borowiec@pollub.pl, Zofia Szmit, PhD Eng., z.szmit@pollub.pl

# Strength of Materials – M37 ❄

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h + Project 15h | ECTS: 5 |
| SEMESTER: winter | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Knowledge of math and physics at an advanced level.

CONTENTS:
Introduction: basic notions. Simple loading cases: tension/compression, torsion, shear, bending – calculation of internal forces and deformation. Geometrical characteristics of cross-sections. Analysis of stress and strain state. Mohr circle. Tensor calculus fundamentals; index notation; transformation of stress and strain. Constitutive Laws. Equations of equilibrium. Combined loads; failure hypotheses. Deflections of beams, shafts and frames; statically indeterminate problems.
Laboratory: Introduction: Organizational activities, strength of adhesive joints; tension; bending; torsion; buckling; finite element analysis; Charpy impact toughness.

EFFECTS OF EDUCATION PROCESS:
Students should gain an intermediate abilities to identify and to solve strength of materials problems.

LITERATURE:

- J.M. Gere & B.J. Goodno: Mechanics of Materials, CENGAGE Learning, 2009;
- R.C. Hibbeler: Mechanics of Materials, Prentice Hall, 2011.

TEACHING METHODS: Multimedia lecture + self-contained projects consulted with the teacher.

ASSESSMENT METHODS: Lecture: final exam, project: defense.

TEACHER: **Sylwester Samborski, PhD Eng.**, s.samborski@pollub.pl, Jakub Rzeczkowski, PhD Eng., j.rzeczkowski@pollub.pl, Aleksander Czajka, MSc Eng., a.czajka@pollub.pl, Izabela Korzec-Strzałka, PhD Eng., i.korzec@pollub.pl

# Mechatronics Systems – M38 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Project |
| NUMBER OF HOURS: Project 45h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basics of mathematics, Mechanics – basic laws. |
| CONTENTS:<br>Programming, Sensors, Actuators, Computing Architectures, Using PC as computing Element, Data Acquisition and Instrumentation, Machine Vision, Artificial Intelligence, Mechatronic Systems Design. |
| EFFECTS OF EDUCATION PROCESS:<br>Understanding significance of mechatronic design. Developing skills in mechatronic design. |
| LITERATURE:<br>• Introduction to Mechatronics and Measurement Systems, David G. Alciatore and Michael B. Histand, Mc Graw Hill, 2003;<br>• The LEGO MINDSTORMS NXT 2.0 Discovery Book. |
| TEACHING METHODS: LEGO Mindstorms NXT |
| ASSESSMENT METHODS: Project. |
| TEACHER: **Przemysław Filipek, PhD Eng.**, p.filipek@pollub.pl |

# Numerical Simulation of Polymer Processing – M40 ❄

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 15h + Project 30h | ECTS: 4 |
| SEMESTER: winter | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge about polymer processing and the ability to using engineering programs.

CONTENTS:
Principles of injection molding process. Basic information about simulation and numerical modelling of polymer processes. Stages of computer simulation of injection molding. Preparing of FEM model of injection molding part. Preparing of runner system. Description of the numerical model of polymer. Simulation of filling phase. Simulation of packing phase. Simulation of cooling phase. Analysis of shrinkage, warpage and deformation. Analysis of other results of simulation of injection molding.

EFFECTS OF EDUCATION PROCESS:
Students gain the ability to perform the simulation of injection molding process using engineering software Cadmould 3D-F and the analysis of its results.

LITERATURE:


- Beaumont J. P., Sherman R., Nagel R. F.: Successful Injection Molding: Process, Design, and Simulation. Carl Hanser Verlag, Munich 2002;
- Rosato D. V., Rosato D. V., Rosato M. G.: Injection Molding Handbook. Kluwer Academic Publisher, Norwell 2000;
- Zhou H.: Computer Modeling for Injection Molding: Simulation, Optimization, and Control. John Wiley & Sons Inc., Hoboken 2013;
- Cadmoul 3D-F. User's Manual. Simcon 2012 (digital version).


TEACHING METHODS: Multimedia lecture + exercises in computer lab under the teacher's guidance.

ASSESSMENT METHODS: Lecture: final exam, computer lab exercises: simple project of injection molding simulation.

TEACHER: **Tomasz Jachowicz, PhD Eng.**, t.jachowicz@pollub.pl

# Theory of Machines and Mechanism I – M44 ❄

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h + Project 30h | ECTS: 6 |
| SEMESTER: winter | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of mathematics.

CONTENTS:
Lecture: Introduction to theory of machines and mechanism; Kinematics of mechanisms: position and displacement, velocity and acceleration; Gear trains; Dynamic analysis: inertia, D'Alembert's principle, motor selection.
Project: (1) Structural analysis: mobility and structural classification of mechanism; (2) Kinematic analysis: velocity and acceleration of links; (3) Dynamic analysis: ratio of planetary gear, motor selection.
Laboratory: Making experiment of didactic test stands: four bar mechanism, crank mechanism, Ackerman mechanism, gear mechanism.

EFFECTS OF EDUCATION PROCESS:
Student know how to make structural and kinematics analysis of typical mechanisms and how to select motor.

LITERATURE:

- Norton R. L.: Design of machinery. McGraw Hill;
- Constans E., Dyer K. B. Introduction to mechanism design with computer applications. CRC Press;
- Uicker J. J., Pennock G. R., Shigley J. E.: Theory of machines and mechanisms. Oxford University Press.


TEACHING METHODS: Presentation, solving examples on the blackboard, test stands.

ASSESSMENT METHODS: Solving problems in the class 15 %; Exam 85 %.

TEACHER: **Łukasz Jedliński, PhD Eng.**, l.jedlinski@pollub.pl, Jakub Gajewski, PhD Eng., j.gajewski@pollub.pl

# Theory of Machines and Mechanism II – M45 ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 30h + Laboratory 15h | ECTS: 6 |
| SEMESTER: summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Finished course Theory of Machines and Mechanism I |
| CONTENTS:<br>Lecture and exercise: Using numerical multibody dynamics method in CAE software to: Analyzing mechanism in static, kinematic and dynamic type of analysis; Defining springs, dampers and bushing; Using profiles and expressions; Creating forces and torques; Defining 3D contact; Working with sub mechanisms; Flexible body analysis<br>Laboratory: Making experiment of didactic test stands: crank slider mechanism (Scotch Yoke), Cardan (Hook, universal) joint, With worth quick return mechanism, gyroscope. |
| EFFECTS OF EDUCATION PROCESS:<br>Student know how to make advanced kinematic and dynamic analysis of mechanisms. |
| LITERATURE:<br>• Norton R. L.: Design of machinery. McGraw Hill;<br>• Constans E., Dyer K. B. Introduction to mechanism design with computer applications. CRC Press;<br>• Uicker J. J., Pennock G. R., Shigley J. E.: Theory of machines and mechanisms. Oxford University Press. |
| TEACHING METHODS: Presentation, computers with CAE software, test stands. |
| ASSESSMENT METHODS: Solving problems in the class 15 %; Exam 85 %. |
| TEACHER: **Łukasz Jedliński, PhD Eng.**, l.jedlinski@pollub.pl Jakub Gajewski, PhD Eng., j.gajewski@pollub.pl |

# Thermodynamics I – M46 ❄

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: winter | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Mathematics – basics of analysis and ordinary differential equations; Physics – basics. |
| CONTENTS:<br>Basic notions, thermodynamic state parameters and functions. Ideal gas laws. Semi-ideal gas model. Ideal gas mixtures. Real gases and vapors. Internal energy, heat, heat capacity, work, enthalpy. First law of thermodynamics: closed system, open system. Reversible/irreversible processes, entropy and second law of thermodynamics. Characteristic processes of ideal and semi-ideal gases. Carnot cycle. Heat engines, thermal cycles. Basic state parameters measurements. Humid air, Mollier diagram and its applications. Basics of combustion process and flue gas analysis. Thermodynamic analysis applications.<br>Optional content: General thermodynamics and third law, thermodynamic properties of gasses, thermodynamic properties of vapors, compressed air, combustion machines, vapor cycles, vapor machines and turbines, cooling cycles and heat pump. |
| EFFECTS OF EDUCATION PROCESS:<br>Student knows: description of state of thermodynamic systems and description of thermodynamic processes, and is able to give statements of basic thermodynamic laws and equations. Student can: effectively solve basic problems of thermodynamics and take measurements of basic thermodynamic properties. |
| LITERATURE:<br>• Thermodynamics. An Engineering Approach 3rd ed., Yunus A. Cengel, Michael A. Boles. McGraw Hill 1998. |
| TEACHING METHODS: Multimedia lecture + problem solving exercises under the teacher’s guidance, laboratory practices. |
| ASSESSMENT METHODS: Lectures and exercises - written exam. Laboratory classes – presence + lab practices reports. |
| TEACHER: **Michał Gęca, PhD Eng.**, m.geca@pollub.pl, Tomasz Łusiak, PhD Eng. t.lusiak@pollub.pl |

# Thermodynamics II – M47 ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 15h + Laboratory 15h | ECTS: 5 |
| SEMESTER: summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Students should have knowledge of mathematics, physics and thermodynamics I. |
| CONTENTS:<br>Second law analysis of systems exergy, irreversibility, Gas power cycles Otto, Diesel, Gas power cycles Stirling, Ericsson, Gas power cycles Brayton air-standard cycles, Vapor power cycles Rankine cycle, Vapor power cycles reheat and regenerative Rankine cycles, Vapor power cycles combined power cycles, Refrigerators and heat pumps vapor-compression refrigeration cycle, Properties of gas mixtures gas-vapor mixtures, Psychrometric properties air-conditioning processes, Chemical reactions first and second law analysis of reacting systems, Chemical reactions fuels and combustion, Chemical and phase equilibrium. |
| EFFECTS OF EDUCATION PROCESS:<br>(1) Conduct calculations and interpret the results of basic thermal processes; (2) Retrieve information from literature and databases and other sources and to interpret and use in calculations; (3) Measure the basic parameters of the heat; (4) He can draw and interpret measurement results; (5) They have practice during laboratory classes and can measure basic thermodynamics parameters; (6) The student uses appropriate methods and apparatus for research. |
| LITERATURE:<br>• Thermodynamics. An Engineering Approach 3rd ed., Yunus A. Cengel, Michael A. Boles. McGraw Hill 1998. |
| TEACHING METHODS: Multimedia lecture + problem solving exercises under the teacher’s guidance, laboratory practices. |
| ASSESSMENT METHODS: Lectures and exercises - written exam. Laboratory classes – presence, lab practices reports. |
| TEACHER: **Michał Gęca, PhD Eng.**, m.geca@pollub.pl,  Tomasz Łusiak, PhD Eng. t.lusiak@pollub.pl |

# Vehicle Dynamics – M48 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Classroom exercises 15h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basic knowledge of physics. |
| CONTENTS:<br>Vehicle definition and basic layout. Wheel–road interaction and tire forces. Drive train and traction force generation. Suspension system – basic models and functions. Longitudinal vehicle dynamics including driving, braking and resistive forces. Fundamentals of lateral dynamics and basic vehicle stability concepts. Equations of motion of a single vehicle. Practical examples and simplified numerical calculations. |
| EFFECTS OF EDUCATION PROCESS:<br>The student understands the basic principles of vehicle dynamics and vehicle motion. The student is able to identify and explain forces and torques acting on a vehicle during driving conditions. The student understands the role of tire–road interaction in vehicle behaviour. The student is able to apply basic equations of motion to calculate vehicle speed and acceleration. The student is able to analyse simple driving scenarios such as acceleration, braking and cornering. |
| LITERATURE:<br>• Georg Rill: Road Vehicle Dynamics: Fundamentals and Modeling;<br>• Massimo Guiggiani: The Science of Vehicle Dynamics: Handling, Braking, and Ride of Road and Race Cars. |
| TEACHING METHODS: Classical and multimedia lectures ; Laboratory – practical experiments. |
| ASSESSMENT METHODS: Lecture – final exam. Exercise – written test. Laboratory – reports. |
| TEACHER: **Mariusz Kamiński, PhD Eng.**, mariusz.kaminski@pollub.pl, Dawid Tatarynow, MSc. Eng., d.tatarynow@pollub.pl |

# Materials Processing Technology – M50 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h + Project 15h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basic knowledge of physics, chemistry and general knowledge related to materials science. |
| CONTENTS:<br>Introduction to materials processing technology. Processing techniques used in manufacturing components from metals and other materials including metal matrix composites. Principles of metallurgy, ferrous and nonferrous metallurgy. Solidification and crystallisation. Casting technologies. Joining techniques, welding, sintering, brazing, and pressure welding. Additive manufacturing of metallic components. Robotic overlay and hardfacing welding. Surface engineering and coatings deposition via thermal spraying and physical processes. Materials nonuniformities evaluation and testing of the materials properties. Effect of processing technology on the macrostructure and microstructure of standard and |
| EFFECTS OF EDUCATION PROCESS:<br>The course covers the processing techniques for manufacturing components from metals and other materials. Students understand the relationship between processing technology and the properties of materials. They also learn methods for castings, weldments, additive manufacturing and quality control of metallic materials. |
| LITERATURE:<br>• M.S.J. Hashmi, Comprehensive Materials Processing, Elsevier, 2024;<br>• Selected online journals accessible via Lublin University of Technology. |
| TEACHING METHODS: Combining theory and practice, group work and reporting, laboratory investigation and experimentation, and project preparation. |
| ASSESSMENT METHODS: Final exam, student's reports, and project evaluation. |
| TEACHER: **Mirosław Szala, PhD Eng.**, m.szala@pollub.pl |

# Fundamentals of Machine Technology and Manufacturing Process Design – M51 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory, Project |
| NUMBER OF HOURS: Lecture 15h + Laboratory 15h + Project 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: General, basics knowledge of cutting, machining, machine technology, technological machines.

CONTENTS:
1. Machine familiarization (Lathe familiarization and Familiarization with milling machine), e.g. Complete machine, Control Panel, Longitudinal slide, Cross slide, Spindle head, Tailstock, Switch cabinet, Components (e.g. Main switch, Clamping pressure display, Chip basin: Coolant lubricant basin). 2. Machine set-up: Setting up the machine (Switching on, Manual movement, Tool compensation, Workpiece zero point), Programing (Write, edit, operate a program). 3. CNC basics: Geometry (e.g. Coordinate systems, Points on workpiece, Absolute, incremental, polar dimension), Technology (speed, cutting rate, feed), Programming (Program structure, header, Addresses, Motion commands, Cutter radius compensation, Tool offsets, Cycles, subroutines). 4. Manufacturing process and its features. Structure of the technological process of machining, components of the process. Construction and technological documentation. Technology of structures in machining. Principles of technological process design. Typical technological processes of basic machine components. Types of semi-finished products. Types of fixed elements (tools and workpieces).

EFFECTS OF EDUCATION PROCESS:
The student knows basic terms in the field of machine technology, has knowledge about the principles of engineering design and design of technological processes of machining. The student is able to design a technological process of manufacturing basic machine components. Getting to know, understanding the basics of construction machines, machine familiarization, machine set-up and CNC basics.

LITERATURE:


- Feld M.: Fundamentals of designing technological processes for typical machine parts;
- Kalpakjian S., Schmid S.: Manufacturing Engineering and Technology in SI Units;
- Youssef H. A.: Manufacturing Technology: Materials, Processes, and Equipment;
- Nee A.: Handbook of Manufacturing Engineering and Technology.


TEACHING METHODS: Combination of theory (lecture) and practice (laboratory/ project), group work and reporting, individual reports/projects or presentations.

ASSESSMENT METHODS: Lectures - final exam. Laboratory / project – mark for report or presentation, the received a course with the mark based on partial marks.

TEACHER: **Ireneusz Zagórski, PhD Eng.**, i.zagorski@pollub.pl, Jarosław Korpysa, PhD Eng., j.korpysa@pollub.pl, Paweł Pieśko, PhD Eng., p.piesko@pollub.pl

# Advanced CNC Programming – M52 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Laboratory |
| NUMBER OF HOURS: Laboratory 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: General, basic knowledge of cutting, machining, machine technology and mechanical engineering.

CONTENTS:

Students will be introduced to the standard terminologies of dialogue CNC programming including: conventions, processes, operations, design and operational characteristics of key hardware components, programming techniques, applications, merits and demerits of CNC machines. The content of the subject includes: fundamentals of CNC milling, familiarization of control panel, advanced content of CNC programming in Heidenhain, functions of CNC dialogue programming, workpiece, tool and coordinate system setting. Part programming techniques in Heidenhain dialogue programming: definition of the tool approach and departure positions relative to the milled contour, linear and circular interpolation definition in cartesian and polar coordinates, definition of allowances – roughing and finishing operations, program transformations – subroutines, mirroring, datum shift, scaling, rotation, presets, probe cycles. Operation of the machine tool - theoretical basics with practical presentation. Preparation of a complete machining program for a 3-axis milling machine tool. Part machining based on programs prepared by students.

EFFECTS OF EDUCATION PROCESS:

Students will know the advanced features in CNC dialogue programming in Heidenhain system. Students will know the specific functions of CNC dialogue programming and programming techniques. Students will know machining and probing cycles required to manufacture and quality control finished part. Students will be able to design and validate technological solutions to defined problems and communicate clearly and effectively for the practical application of their work.

LITERATURE:

- Programming of numerically controlled machines (various authors);
- Journals on-line;
- Heidenhain TNC 640 Handbook.

TEACHING METHODS: Combination of theory (lecture) and practice (project), individual programming exercises, discussion.

ASSESSMENT METHODS: Laboratory – final project. Project will include complete CNC program made with Heidenhain dialogue programming.

TEACHER: **Kamil Anasiewicz, PhD Eng.**, k.anasiewicz@pollub.pl, Paweł Pieśko, PhD Eng., p.piesko@pollub.pl

# Computer Aided Manufacturing (CAM) – M53 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Laboratory |
| NUMBER OF HOURS: Laboratory 15h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: General, basic knowledge of cutting, machining, machine technology and mechanical engineering.

CONTENTS:
The subject focuses on the introduction of modern computer-aided manufacturing technologies. Students will develop practical knowledge and understanding of the applications, underlying technological principles and limitations of these technologies through tutorials and students made projects. Contents of the subject includes: fundamentals of CAM software, overview of machining processes, familiarization of basic functions of CAM software, programming skills for computer numerical control (CNC) machines, fixture concepts, design and milling operation setup, CAM cycles. Preparation of production documentation for the operator.

EFFECTS OF EDUCATION PROCESS:
Students will be able to design a manufacturing process for an industrial component by interpreting 3D part model / part drawings with use of CAM technology through programming, setup, and ensuring safe operation of CNC machine tool. Students will be able to design and validate technological solutions to defined problems and communicate clearly and effectively for the practical application of their work. Students will be able to apply the concepts of machining for the purpose of selection of appropriate machine tool, machining parameters, select appropriate cutting tools for CNC milling and turning. Students will learn to create the technical documentation for selection of suitable manufacturing technologies as well as manufacturing documentation for CNC machine tool system for operations using appropriate 3-axis/multi-axis CNC technology.

LITERATURE:
- Computer Control of Manufacturing Systems;
- CAM machining methods (various authors);
- Journals on-line;
- CAM software tutorials.

TEACHING METHODS: Combination of theory (lecture) and practice (project), individual programming exercises, discussion.

ASSESSMENT METHODS: Laboratory – final project. Project will include complete CNC program made with CAM software including 3D workpiece, clamping, tool, toll paths, cutting parameters, workshop documentation.

TEACHER: **Kamil Anasiewicz, PhD Eng.**, k.anasiewicz@pollub.pl, Paweł Pieśko PhD Eng., p.piesko@pollub.pl

# Numerical Simulations of Materials – M54 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

PRELIMINARY REQUIREMENTS: Materials engineering – basics; mechanics of materials – basics.

CONTENTS:
Lecture: Introduction to ABAQUS/CAE (Computer Aided Engineering) software. Introduction to the numerical simulations of engineering materials such ceramics, polymers, metals and composites; boundary conditions in numerical simulations; mathematical material models; mechanical and thermal loadings; contacts; introduction to modelling of material failure; defining failure criteria.
Laboratory: Introduction to ABAQUS/CAE software. Modelling of material response due to thermal and mechanical loadings; defining boundary conditions; defining material properties for ceramics, polymers, metals and composites; defining contact between two materials; simulations including material failure.

EFFECTS OF EDUCATION PROCESS:
Students knows methods of numerical simulation of engineering materials and structures in ABAQUS CAE software. Students can perform simple numerical simulation. Students are aware of the material models and their assumptions applied in numerical simulations. Obtain skills of the discretization of engineering structures, defining material properties, contacts, and boundary conditions in ABAQUS software. Students are able to analyze obtained result with selection of particular history output of the simulations.

LITERATURE:
- ABAQUS 6.14 Documentation. Dassault Systemes Simulia Corp. 2014. Providence, RI, USA;
- J.N. Reddy - An Introduction to the Finite Element Method, Third Edition. McGraw-Hill Education; 3 edition, 2005;
- E.J. Barbero - Finite Element Analysis of Composite Materials Using ABAQUS. CRC Press, Taylor & Francis Group, 2013;
- H. Ataei, M.Mamaghani - Finite Element Analysis Applications and Solved Problems using Abaqus®, Create Space, 2017.

TEACHING METHODS: Multimedia lecture, discussion, exposition. Working on the computers in ABAQUS/CAE software.

ASSESSMENT METHODS: Assessment of the numerical simulation results, assessment of the results reports, partial colloquia.

TEACHER: **Kazimierz Drozd, PhD Eng.**, k.drozd@pollub.pl

# Aviation Propulsion Systems – M55 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Knowledge of physics, mechanics, thermodynamics.

CONTENTS:
Operating conditions of aircraft propulsion systems. Classification of aircraft propulsion systems and their applications. Principle of operation, basic design, components, classification and design variations of aviation propulsion systems: piston, turbine and jet engines, propeller, rotor and transmission power units. Propulsion systems of helicopters, airframes and vertical take-off and landing aircraft. Design analysis of selected aircraft power units. Calculation of energy flow and loads in selected power units. Study of the design of selected power units. Development of the characteristics of a selected power unit.

EFFECTS OF EDUCATION PROCESS:
Familiarity with aircraft propulsion systems classification. Familiarity with the fundamentals of aircraft propulsion systems. Familiarity with the theoretical basis of operation of major components of aircraft propulsion systems. Ability to identify and describe aircraft propulsion system components. Ability to carry out basic aircraft propulsion system calculations.

LITERATURE:

- J.B. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill, 1988;
- Aviation Maintenance Technician Handbook – Powerplant. FAA-H-8083-32. U.S. Department of Transportation Federal Aviation Administration;
- Mattingly J., Heiser W., Pratt D.: Aircraft Engine Design, American Institute of Aeronautics and Astronautics, Education Series, Inc. 1801 Aleksander Bell Drive, Reston, VA20191-4344, 2002. Gunston, B.: The Development of Piston Aero Engines. Haynes Publishing; 2 edition 2006. ISBN 978-1852606190;
- Rodriquez, Ch. L.: Propellers for Aircraft Maintenance Technician EASA Module 17A, Aircraft Technical Book, 2016. ISBN 9781941144367.

TEACHING METHODS: Multimedia lecture + laboratory experiments+ self-contained project consulted with the teacher. Students attend the lecture and have practice during the laboratory and project classes. Construction analysis laboratory. Computational exercises.

ASSESSMENT METHODS: Lecture: final exam; project: discussion.

TEACHER: **Michał Gęca, PhD Eng.**, m.geca@pollub.pl

# Introduction to Computational Fluid Dynamics – M56 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic of analysis, partial and ordinary differential equations, physics – basic laws.

CONTENTS:
Introduction: Computational Fluid Dynamics, Impact of CFD on engineering applications, Merits of CFD. Discretization: Basic aspects, Techniques – Introduction to FDM, FVM and FEM, Finite differences, Explicit and Implicit approaches, Error and Stability analysis, Implementation of boundary conditions using FDM and FVM. Grid Generation: General transformation of the equations, Stretched grids, Elliptic grid generation, Adaptive grids. Fluid Dynamics: Models of the flow, Reynold's Transport Theorem, The continuity equation, Momentum Equation, Energy equation, Physical boundary conditions, Forms of governing equations suited for CFD. Numerical Techniques for Heat Conduction, Convection and Diffusion,: Steady one-dimensional convection and diffusion, Discretization equation for two and three dimensions, A One-way space coordinate, False Diffusion. Turbulence Modelling: Nature, Description and Characterization of turbulent flow, Turbulent models for RANS equations.

EFFECTS OF EDUCATION PROCESS:
At the end of the course the student will be able to Formulate equations for fluid flow and heat transfer problems, Understand the basic concepts of CFD techniques, Solve conduction and convection & diffusion problems, Solve incompressible fluid flow problems and Use FLUENT to solve problems.

LITERATURE:

- Text Book(s): John D Anderson (2012);
- Computational Fluid Dynamics – The Basics with Applications, 1st Edition, McGraw Hill.

TEACHING METHODS: Lecture, computational tasks.

ASSESSMENT METHODS: Final exam based on compiling theory or homework assignments; reports, test or project evaluation.

TEACHER: **Grzegorz Litak, Prof. PhD**, g.litak@pollub.pl, Michał Gęca, PhD Eng., m.geca@pollub.pl

# Fundamentals of Finite Element Analysis – M57 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of calculus, physics, and mechanics; basic MATLAB programming knowledge (not compulsory).

CONTENTS:
(1)Basics of Linear Algebra, Introductory calculus, Introduction to finite element (FE) analysis: Introduction to weighted residual and variational methods; Differential equations and strong formulation of structural elements, Principle of minimum potential energy and weak formulation - Galerkin and Rayleigh-Ritz methods; (2) 1-dimensional spring, bar, truss and beam elements; 2D elements: Linear and Constant strain triangle elements, Quadrilateral element; Practical considerations in FEM modeling - Convergence of analysis of results; Higher order elements - Isoparametric formulation; Numerical integration; (3) Modelling of 1D/2D/3D static and dynamic structural problems with mechanical and thermal loads, verification of FE models using software applications – ABAQUS and ANSYS CAE. Introduction to nonlinear FE problems.

EFFECTS OF EDUCATION PROCESS:
Students will be able to: Prepare mathematical model of structures, solve for analytical solutions, and prepare FE models using MATLAB/Python; setup models, mesh, and post-processing of results, selection of failure criteria in ABAQUS and ANSYS. For research and CAE engineer aspirants: establish strong understanding about backend functioning of most commercial FE softwares; improve understanding about usage and setting up models in commercial FE softwares; prepare the students for advanced/nonlinear FE modelling.

LITERATURE:

- Finite Element Procedures, K. J. Bathe, PHI Learning Pvt. Ltd, 1996;
- The Finite Element Method, T.J.R. Hughes, Dover, 2000, McGraw-Hill, 1995;
- Fundamental finite element analysis and applications: with Mathematica and Matlab, M. Asghar Bhatti, Wiley, 2005;
- Fish, J., Belytschko, T. (2007). A first course in finite elements. United Kingdom: Wiley.

TEACHING METHODS: Combination of white-board teaching (70%) and presentations (30%); Live MATLAB coding, modelling, and software simulation sessions for interactive participation; Use of physical and virtual models as required.

ASSESSMENT METHODS: 2 quiz or 1 mid-semester exam, end semester/final exam, assignments, and/or course project.

TEACHER: **Grzegorz Litak, Prof PhD**, g.litak@pollub.pl

# Computer Aided Engineering (CAE) – M58 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Laboratory |
| NUMBER OF HOURS: Laboratory 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: No additional requirements.

CONTENTS:
Introductory classes, safety training, credit rules, the division into subgroups, schedule of classes, introduction to CAE. MathCAD/Matlab: Introduction, examples of software capabilities, simple calculations, document creating, the directory structure, system commands. Commands, data types, complex commands, expressions. Simple calculations, creating a document - definitions, variables, range variables, etc. Editing tools, texts, equations and calculations, sample algebra calculations, matrices and chains, matrix operators. Numbers, functions and mathematical constants, basic functions and constants, elemental operations, matrix and array arithmetic, numerical issues. Complex data types, the use of functions and operators. Two-dimensional graphics and three-dimensional graphics. Symbolic and numerical computation. Examples applications in data obtained in the engineering measurements analysis.

EFFECTS OF EDUCATION PROCESS:
Students will know advanced CAE software. Will be able to select appropriate tools of computer technology to solve engineering tasks. Students will be able to analyse and interpret the results of technical calculations applying computer tools. Will be prepared for professional work with the support of computer techniques.

LITERATURE:

- Computer-Aided Engineering for Manufacture. Milner D. A. (Douglas A.);
- Essential PTC® Mathcad Prime® 3.0 : A Guide for New and Current Users. Maxfield Brent;
- Engineering with Mathcad : using Mathcad to create and organize your engineering calculations. Maxfield Brent;
- Essential MATLAB for engineers and scientists. Valentine Daniel T;
- Numerical methods : using MATLAB. Lindfield G. R. (George R.);
- A MATLAB companion for multivariable calculus. Cooper Jeffery.

TEACHING METHODS: Students will work with the computer and will do the examples given from teacher. Multimedia presentations and explanations by the teacher.

ASSESSMENT METHODS: Practical test with the use of CAE. Assessment will depends on the level that student will reach.

TEACHER: **Dariusz Mazurkiewicz, Prof. PhD Eng.**, d.mazurkiewicz@pollub.pl, Paweł Pieśko, PhD Eng., p.piesko@pollub.pl

# CAD Engineering Drawing – M59 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 16h + Laboratory 60h | ECTS: 6 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: No additional requirements.

CONTENTS:
Lecture: CAD systems. 3D design methods. Create drawings based on 3D parts. Introduction to projection idea. Definitions of projection elements. Monge projection. Sections and sectional views. Screw thread. Nuts, bolts, screw and washer. Worked examples in machine drawing. Limits and fits. Surface texture. Production drawings. Standards engineering. Laboratory: The field of three-dimensional software engineering encompasses computer-aided design systems, which are utilized for the creation of various types of models. Students design machine parts and assemblies using SolidEdge software: Draft, Part, Assembly.

EFFECTS OF EDUCATION PROCESS:
Students know the idea of computer aided design process. Student understand the concept of engineering graphics. Student is able to design and assembly 3D machine parts. Student can create 2D engineering documentation.

LITERATURE:

- Engineering Drawing and Design, Dawid A. Madsen; Solid Edge 2024 Basics and Beyond.

TEACHING METHODS: Presentation, solving examples, projects.

ASSESSMENT METHODS: Assessment based on projects done during the semester.

TEACHER: **Jakub Gajewski, PhD Eng.**, j.gajewski@pollub.pl, Michał Rogala, PhD Eng., m.rogala@pollub.pl, Łukasz Jedliński PhD Eng., l.jedlinski@pollub.pl

# AI and ML Applications in Engineering – M60 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Classroom exercise 15h + Laboratory 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 5 |

PRELIMINARY REQUIREMENTS: No additional requirements.

CONTENTS:
Lecture (15h): Intro to AI/ML; tools (Python, R); data fundamentals (types, preprocessing, visualization); ML algorithms (supervised/unsupervised, classification, regression, clustering); deep learning basics (neural networks, CNNs); AI applications in engineering (design, planning, diagnosis, operation).
Exercises (15h): Intro to Python and key tools. Data collection, cleaning, and basic visualization. Implementation of simple prediction and classification models. Mini-project integrating data analysis and model building.
Labs (15h): Advanced ML project using neural networks, ML for image processing with CNNs, Extended case study on an engineering problem.

EFFECTS OF EDUCATION PROCESS:
Students will gain a foundational understanding of AI and ML, learning to use Python and key libraries for basic tasks. They'll develop skills in data preprocessing and visualization, and the ability to implement simple machine learning models and neural networks. The course offers practical experience in data collection and applying AI to engineering problems, including an introduction to predictive maintenance.

LITERATURE:
- Jake VanderPlas Python Data Science Handbook, O'Reilly Media, 2022;
- J. Paolo Davim, Antonio Sartal, Diego Carou Machine Learning and Artificial Intelligence with Industrial Applications, Springer, 2022.

TEACHING METHODS: Multimedia lecture, calculation projects; computer laboratory – practical experiments.

ASSESSMENT METHODS: Lecture - exam. Laboratory – the received a course with the mark based on partial marks from reports and class activity.

TEACHER: **Mariusz Kamiński, PhD. Eng.**, mariusz.kaminski@pollub.pl, Dawid Tatarynow, MSc. Eng., d.tatarynow@pollub.pl

# Fundamentals of Light Aircraft Engineering – M61 ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: None

CONTENTS:
(1) Basic definitions and terms related to aircraft engineering, definitions of aircraft types, classification and design types of light aircraft. (2) Aircraft flight mechanics, flight envelope, operational limitations, balance. (3) Aircraft design (light aircraft design, helicopter design, rotorcraft design, multi-rotorcraft design, essential components of aircraft design). (4) Structural components of light aircraft fuselages and wings. (5) Aircraft systems (electrical, hydraulic, pneumatic, fuel, anti-icing systems - construction, principle of operation, construction variations, examples of construction, differences in construction in different types of aircraft). (6) Avionics (definition, types of avionics systems, purpose and use, examples of systems and configurations in aircraft). (7) Materials used in light aircraft.

EFFECTS OF EDUCATION PROCESS:
Familiarisation with aviation-related terms; Familiarisation with the basic aircraft components; Familiarisation with the structure and function of the basic installations and equipment of aircraft; Familiarisation with the structural solutions, materials and joining technologies used in light aircraft.

LITERATURE:

- Federal Aviation Administration „Aviation Maintenance Technician Handbook – General" FAA-H-8083-30A, 2018;
- Federal Aviation Administration „Aviation Maintenance Technician Handbook – Airframe" FAA-H-8083-31, 2012.

TEACHING METHODS: Lectures, laboratory classes, visits to aviation companies.

ASSESSMENT METHODS: Exam.

TEACHER: **Jacek Czarnigowski, PhD Eng.**, j.czarnigowski@pollub.pl

# Development of the Design of Commercial Vehicles and Their Bodies – M62 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise |
| NUMBER OF HOURS: Lecture 30h + Classroom exercise 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of mechanics, necessary to understand the basic phenomena occurring in machine construction; basic knowledge in the design, construction and production of machines, especially wheeled means of transport: trucks, trailers and semitrailers.

CONTENTS:
Classification, definitions and concepts related to wheeled means of transport; requirements and expectations of customers of transport services provided by wheeled means of transport; types of wheeled means of transport, legal requirements; conditions of operation; functional systems of modern trucks: engines and exhaust systems, drivetrain, brakes and retarders, suspensions, active driver assistance systems; current development trends in truck construction; commercial vehicle bodies: classification, areas of use, construction details, customer requirements; construction of the most important types of bodies; additional equipment for commercial vehicles; methodology for selecting and designing specialized bodies.

EFFECTS OF EDUCATION PROCESS:
Students should gain basic knowledge necessary to understand the technical, ecological, economic and social conditions of the functioning of wheeled means of transport; in-depth and structured knowledge of the directions of development of the structure and conditions related to the operation of commercial vehicles; ability to select components of commercial vehicles: trucks and towed vehicles and their bodies depending on the application.

LITERATURE:

- truck OEM and bodybuilders internet portals and product information;
- OEM bodybuilders manuals;
- J. Epker: Lastkraftwagen und Technik;
- EPJOS Verlag, 2015;
- Fundamentals of commercial vehicle technology;
- MAN Truck & Bus, 2005.

TEACHING METHODS: Multimedia lecture + problem solving exercises under the teacher’s guidance.

ASSESSMENT METHODS: Lecture: final exam, classroom exercises: evaluation of exercises performed during classes.

TEACHER: **Dariusz Piernikarski, PhD Eng.**, d.piernikarski@pollub.pl

# Optimization of the Total Cost of Ownership of Commercial Vehicles – M63 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 30h + Project 15h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge the design, construction and production of machines, especially wheeled means of transport: trucks, trailers and semitrailers; basic knowledge of economics, necessary to understand the most important phenomena occurring on the freight transport market; basic knowledge of economic, technological and ecological aspects of machine operation.

CONTENTS:
General conditions of transport activities; characteristics of the freight transport services market; economic, technological and ecological aspects of operation of commercial vehicles; basic terms and definitions related to the total cost of ownership (TCO) of the commercial vehicle; technical and organizational possibilities to increase operational efficiency; FMS standard as an data transmission interface; tasks and functionalities of fleet management systems; data analysis and generation of reports; use of fleet management systems for monitoring of rolling stock and drivers; real-time evaluation of fleet performance on the basis of existing fleet management systems.

EFFECTS OF EDUCATION PROCESS:
Students should gain basic knowledge in the field of technical, economic and ecological aspects of the operation of road freight transport means; be able to qualitatively and quantitatively assess the effects of actions taken to improve the total cos of ownership; have the ability to select components of commercial vehicles: trucks and towed vehicles, depending on the application.

LITERATURE:
- truck OEM internet portals and product information;
- Jean-Paul Rodrigue: The Geography of Transport Systems, New York: Routledge, 2020.

TEACHING METHODS: Multimedia lecture + problem solving exercises and final project under the teacher's guidance.

ASSESSMENT METHODS: Lecture: final exam, classroom exercises: evaluation of final project.

TEACHER: **Dariusz Piernikarski, PhD Eng.**, d.piernikarski@pollub.pl

# Mechanics of Composite Materials – M64 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture |
| NUMBER OF HOURS: Lecture 30h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 7 |

PRELIMINARY REQUIREMENTS: Algebra, fundamentals of general mechanics, fundamentals of mechanics of materials.

CONTENTS:

1. Introductory comments, characteristics of composite materials, classifications, terminology; 2. Advantages & disadvantages of composite materials; manufacturing techniques for composite materials; composite types & layout; 3. Micromechanics of composite layer; homogenization; 4. Homogenization cont.; Reuss and Voight equivalent models; 5. Equivalent mechanical properties of a composite material; 6. A review of strain, stress and material behaviour; 7. Constitutive law for different materials; 8. Mechanical response of a laminae - 3D Hook law; thermal & hygral effects; 9. Plain stress states, simplifications to the 3D Hook law; 10. Unidirectional fibre reinforced composite material in plane stress state in local coordinate system; 10. Mechanical properties of fibre reinforced composite material in global coordinate system;
11. Classical Laminate Theory; 12. Beams and plates made of composite material; 13. Mechanical test methods for laminae & laminates; 14. Composite materials failure theories.

EFFECTS OF EDUCATION PROCESS:

1. Student can distinguish and describe macroscopic properties of homogeneous and heterogeneous materials using mathematical relationships; isotropic, transversely isotropic, monotropic, orthotropic and anisotropic materials; 2. Student knows the basic concepts of micro and macromechanics of composites; knows computational models of composite mechanics (Voight model, Reuss model, mixture rule, etc.); 3. Student can discuss the assumptions of computational models of laminates, and the assumptions of the Classical Laminates Theory.; 4. Student knows the basic types of layer stacking sequences of multi-layer laminates and is capable to formulate constitutive relationships in these materials; 5. Student can solve static load problems of basic structural elements made of multilayer laminates.

LITERATURE:


- Daniel I.M., Ishai, O.: Engineering Mechanics of Composite Materials, Oxford University Press, New York – Oxford, 1994, ISBN 0-19-507506-4;
- Kollar L., Springer G.S.: Mechanics of Composite Structures, Cambridge University Press, Cambridge, 2003, ISBN 0-521-80165-6;
- Reddy, J.N.: Mechanics of Laminated Composite Plates and Shells: Theory and Analysis, CRC Press, Boca Raton 2000, ISBN: 0-8493-1592-1;
- Staab G.H.: Laminar Composites. Butterworth-Heinemann, 2010, ISBN: 0-7506-7124-6.


TEACHING METHODS: Lecture talk, media presentations, solving numerical examples.

ASSESSMENT METHODS: Written upon completing the course.

TEACHER: **Jarosław Latalski, PhD Eng.**, j.latalski@pollub.pl

# Numerical Data Processing and Analysis – M65 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Fundamental knowledge of mathematics and physics.

CONTENTS:
Introduction to MATLAB. Matrix operations. Mathematical formulas and discretisation. Scripts – programming. Graphical presentation of data. Data types. Disk operations. Functions. Basic numeral problems: differentiation, integration, solving a nonlinear equation. Examples of the use of matrices in scientific problems (vectors rotation, eigenvalue problem). Curve fitting to data points. Solving differential equations. Modelling of dynamical systems.

EFFECTS OF EDUCATION PROCESS:
Students should be able to use Matlab to process experimental data, perform basic numerical analyses, numerically solve selected scientific problems, and graphically present data and numerical results.

LITERATURE:

- Matlab help system;
- Numerical methods, an Introduction with Applications Using Matlab. A. Gilat, V. Subramaniam, J. Wiley & Sons., Inc. (2011).

TEACHING METHODS: Lecture – multimedia presentation and traditional board. Laboratory – practical exercises and discussion (computer lab).

ASSESSMENT METHODS: Lecture and laboratory: practical exam- solving problems with computer. Laboratory reports.

TEACHER: **Andrzej Rysak, PhD**, a.rysak@pollub.pl, Jakub Szabelski, PhD Eng., j.szabelski@pollub.pl

# Industrial Transportation Devices – M66 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 15h + Project 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Mathematics, physics, fundamentals of machine design.

CONTENTS:
Lectures include: issues related to the essence and importance of industrial transport devices, determining selected parameters of moved materials. In addition, knowledge about the purpose, characteristics, structure and operating parameters of devices used in internal transport. Integration of transport devices with production, assembly and robotics purposes. Safety of use of internal transport means, Construction, operation and operation of internal transport means. Issues related to the use of means of transport and monitoring the technical condition of selected transport devices. The exercises include: issues related to determining work parameters and the selection of devices used in internal transport.

EFFECTS OF EDUCATION PROCESS:
Has knowledge of basic concepts related to internal transport. Distinguishes between means of transport, knows the criteria for their classification contained in the standards and is able to divide them. Knows the principle of operation, purpose, construction and adjustment possibilities of internal transport devices. Is able to perform engineering calculations related to determining the operating parameters of transport devices and selecting appropriate means for the prevailing conditions and for carrying out specific activities. Is able to operate, organize and control the operation of internal transport equipment. Is able to determine the parameters of moved loads affecting the operation of continuous transport devices. Knows the safety rules related to work performed using internal transport equipment. Is able to use analytical and simulation methods and basic IT techniques to improve engineering activities.

LITERATURE:

- Ryba T., Bzinkowski D., Siemiątkowski Z., Rucki M., Stawarz S., Caban J., Samociuk W. Monitoring of Rubber Belt Material Performance and Damage. Materials 2024, 17, 765. https://doi.org/10.3390/ma17030765;
- Caban J., Nieoczym A., Misztal W., Barta D. Study of operating parameters of a plate conveyor used in the food industry. IOP Conference Series: Materials Science and Engineering 2019, 710, 012020IOP. doi:10.1088/1757-899X/710/1/012020;
- Caban J., Rybicka I. The Use of a Plate Conveyor for Transporting Aluminum Cans in the Food Industry. Advances in Science and Technology Research Journal, Vol. 14, Is. 1, 2020, pp. 26–31, https://doi.org/10.12913/22998624/113283.

TEACHING METHODS: 1. Lectures; 2. Solving accounting tasks; 3. Project; 4. Preparation of reports.

ASSESSMENT METHODS: Test, evaluation of reports and project.

TEACHER: **Jacek Caban, PhD Eng.**, j.caban@pollub.pl

# Foundation of Automation – M67 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 15h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Mechanics, physics.

CONTENTS:
Mathematical modelling of dynamical systems; differential equations, description in the state space; application of Laplace transforms, transfer function; non-linear systems, operating point of the system, linearization. Classification of dynamical systems; time responses, frequency characteristics, stability of systems, stability criteria, Nyquist's theorem; Synthesis of the control system; system with a PID controller, structures of control systems, compensation selection of settings of PID controllers; correction of the system; systems with internal model (IMC), Robust control. Two-position control, time discretization, Z-transformation, control in systems containing discrete time components, discrete PID controller

EFFECTS OF EDUCATION PROCESS:
The student has basic knowledge in the field of control theory: he/she knows selected methods of mathematical description (modelling) of dynamical systems, determination of system responses and stability testing. The student can identify the properties of the control object and design a simple control system, including automatic control system; is able to properly select the control structure and algorithm parameters, perform stability analysis and assess the quality of control, including the use of calculation and simulation tools.

LITERATURE:
- Steven L. Brunton, J. Nathan Kutz, Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control, Cambridge University Press 2019;
- Harold Klee and Randal Allen, Simulation of Dynamic Systems with MATLAB® and Simulink, Taylor & Francis 2018.

TEACHING METHODS: Lecture with projector, projects in computer laboratory using Matlab-Simulink environment.

ASSESSMENT METHODS: Final test and project.

TEACHER: **Grzegorz Litak, Prof. PhD**, g.litak@pollub.pl

# Mobile Robots – M68 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 30h + Project 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Knowledge of the basics of mechanical engineering, fundamentals of programming and robotics.

CONTENTS:
(1) Classification of mobile robots; (2) Construction of mobile robots; (3) Introduction to the control system and programming; (4) Drives of mobile robots; (5) Sensors in mobile robots; (6) Odometry in mobile robots; (7) Tags and maps in mobile robots; (8) Planning of mobile robots; (9) Hierarchical and behavioural control; (10) Applications of mobile robots.

EFFECTS OF EDUCATION PROCESS:
Student has a basic knowledge of the general types of mobile robots; Student knows the basic principles of building mobile robots; Student knows the components to build a mobile robot.

LITERATURE:

- Tzafestas, Spyros G. Introduction to mobile robot control. Elsevier, 2013;
- Nehmzow, Ulrich. Mobile robotics: a practical introduction. Springer Science & Business Media, 2012;
- Dixon, Warren E., et al. Nonlinear control of wheeled mobile robots. Vol. 175. London: Springer, 2001.

TEACHING METHODS: Lecture with multimedia presentation, Project – two individual project, task solving - design of robot movement along a specified trajectory, design of robot motion along a track with obstacles.

ASSESSMENT METHODS: Lecture – the received a course with the mark; Project – the received a course with the mark based on partial marks from prepared projects, reports on performed exercises.

TEACHER: **Izabela Miturska-Barańska, PhD Eng., i.miturska@pollub.pl**, Elżbieta Doluk, PhD Eng., e.doluk@pollub.pl

# Vision Measurement Systems – M69 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 30h + Project 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Basic knowledge of mathematics, physics, information technology, metrology, statistics and quality control. |
| CONTENTS:<br>Vision inspection systems (machine vision) – introduction. Construction and applications of automatic vision inspection systems. Image acquisition systems, properties of digital image acquisition. Low-level image processing methods. Algorithms for highlighting of high-level features. Developing procedures for vision systems, software for designing vision systems. Lab: Designing a computer programs for object identification and geometric measurements. |
| EFFECTS OF EDUCATION PROCESS:<br>The knowledge of the construction and operation of computer vision inspection systems and the use of vision inspection systems in various industries. |
| LITERATURE:<br>• Sources materials available online in English. |
| TEACHING METHODS: Lecture with multimedia presentation. Exercises in a computer laboratory. |
| ASSESSMENT METHODS: A set of completed exercises. Self-prepared project. Written test "knowledge survey". |
| TEACHER: **Piotr Wolszczak, PhD Eng.**, p.wolszczak@pollub.pl |

# Operations Management – M70 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 10h + Laboratory 20h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: None |
| CONTENTS:<br>Introduction to operations management. Traditional and future production systems. Production preparation processes. Modern methods of organizing production processes in production systems. Comprehensive methods of organizing production and enterprise management. Demand forecasting in the context of designing production plans. Production planning. Determining the length of the production cycle for a product. Building a production schedule. |
| EFFECTS OF EDUCATION PROCESS:<br>The student knows in the field of shaping the production process in automated and robotic production systems. The student knows the parameters used to describe and evaluate the efficiency of the production process. |
| LITERATURE:<br>• Stevenson W.J., Operations management, McGraw-Hill Education, New York, 2021;<br>• Reid R.D., Sanders N.R., Operations management, Wiley, 2019;<br>• Kumar S.A., Operations management, New Age International P Ltd., Publishers, New Delhi, 2009;<br>• Slack N., Brandon-Jones A., Essentials of operation management, Pearson, 2018;<br>• Jackson J., Operations management. Concepts and Applications, Murphy & Moore, 2022. |
| TEACHING METHODS: Work in groups. Work with computer. Case studies. |
| ASSESSMENT METHODS: Reports on performed laboratory exercises. |
| TEACHER: **Arkadiusz Gola, PhD Eng.**, a.gola@pollub.pl, Katarzyna Piotrowska, PhD Eng., k.piotrowska@pollub, Ewelina Kosicka MSc. Eng., e.kosicka@pollub.pl |

# Pneumatics and Hydraulics – M71 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 15h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: No additional requirements

CONTENTS:
Introduction: scope of application of pneumatic and hydraulic drives, open-loop and closed-loop control, characteristics of working media, pressure ranges dedicated to specific constructions. Schematic diagrams and functional elements of drives used in open-loop and closed-loop systems, static and dynamic properties of individual elements. Fundamentals of drive design: calculating loads, requirements for working medium flow speed, calculating the speed of actuating devices. Calculating flow resistances, energy storage. Thermal processes, noise reduction. Basic constructions of working elements and their intended use: pumps, linear and rotary motors. Valve and distributor constructions, proportional valves, accumulators. Designs of power supply units and hydrostatic and hydrodynamic drives. Designs of special devices: high-power couplings, overload systems, cooling systems and their properties. Preparation of the working medium and its properties, air preparation stations, fluid filtration, properties of fluids and their measurement. Designing servodrives: calculating speed, calculating natural vibration frequencies. Calculating damping, adjusting damping, calculating total gains, calculating response times and shaping them. Control of distributed systems, creating graphs of operating states of technical devices. Technical devices of distributed control systems: valve islands, positioning measurement techniques of working elements, data transmission systems, specialized controllers. Overview of the designs of complex pneumatic and hydraulic drives.

EFFECTS OF EDUCATION PROCESS:
Student is familiar with the fundamentals of pneumatic and hydraulic drive technology, their properties and application in the construction of technological machines and special-purpose machines.

LITERATURE:
- Andrew Parr, Hydraulics and Pneumatics. A Technician's and Engineer's Guide. Elsevier, Butterworth-Heinemann, 2011;
- K. Hiraniya Singh, Pneumatic and Hydraulic Systems. I.K. International Publishing House Pvt. LTD, 2017;
- Md. Abdus Salam, Fundamentals of Pneumatics and Hydraulics. Springer, 2022.

TEACHING METHODS: Lecture: multimedia presentation; Laboratory: practical experiments.

ASSESSMENT METHODS: Lecture: exam; Laboratory: laboratory reports.

TEACHER: **Jakub Skoczylas PhD Eng.**, j.skoczylas@pollub.pl, Grzegorz Litak, Prof. PhD, g.litak@pollub.pl

# Differential Equations – M72 ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Classroom exercise |
| NUMBER OF HOURS: Lecture 15h + Classroom exercise 15h | ECTS: 3 |
| SEMESTER: summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 8 |

| |
|---|
| PRELIMINARY REQUIREMENTS: Calculus. Mathematical analysis. Algebra of matrices. |
| CONTENTS:<br>(1) first order ordinary differential equations (separable d.e., linear d.e., Bernoulli d.e., exact d.e.); (2) linear second order differential equations (homogeneous and nonhomogeneous) with constant coefficients; (3) linear second order differential equations (homogeneous and nonhomogeneous) with variable coefficients; (4) systems of linear equations; (5) the method of Laplace transform in solving ODEs. |
| EFFECTS OF EDUCATION PROCESS:<br>Student knows: first order ordinary differential equations; linear second order differential equations; systems of linear equations; the method of Laplace transform. Student can: solve first order and second order differential equations; solve systems of linear equations; apply Laplace transform in solving differential equations and systems of differential equations. |
| LITERATURE:<br>• R.Nagle, E.Saff, A.Snider – Fundamentals of differential equations. Addison Wesley Longman Inc. |
| TEACHING METHODS: Lectures +classroom exercises. |
| ASSESSMENT METHODS: Final written exam. |
| TEACHER: **Paweł Zaprawa, PhD Eng.**, p.zaprawa@pollub.pl |

# Surface Engineering, Welding and Joining Technology – M73 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of physics, chemistry and general knowledge related to materials science.

CONTENTS:
Introduction to surface engineering; Surface phenomena and surface layers; Tribology and wear mechanisms; Methods of tribological testing; Fundamentals of lubrication technology; Surface layer modification technologies; Coating technologies and materials, types of coatings; Deposition of coatings from chemical phase; PVD methods and their application; Electron beam technology; Ion implantation; Selected thermo-chemical treatments-boriding, nitriding, carburizing; Nanostructured coatings; Thermal spraying; Experimental methods used to assess properties of superficial layer. Metallurgy of welding, weldability; Phenomena occurring in electric arc; Shielded arc methods: GMA, GTA, SAW; Welding with cored wires; Gas welding; Hardfacing and pad welding; Laser welding; Electron beam welding; Cutting methods; Resistance, friction and flush welding techniques; Soldering and brazing; Welding of structural ferrous and nonferrous materials and advanced materials; Welding of polymers; Robotization and automatisation of welding and coatings deposition. Additive processing of materials and Wire Arc Additive Manufacturing.

EFFECTS OF EDUCATION PROCESS:
The student knows the criteria for selecting surface engineering and welding technologies and their parameters; methods for friction and wear control and damage mitigation; the standard and modern methods applied to join materials. The student also knows the materials and properties of components fabricated via specific surface engineering and welding and evolution of material properties and functionality caused by different processing conditions.

LITERATURE:
- L. Pawłowski, Physical Deposition Methods for Films and Coatings. John Wiley & Sons, 2025;
- T. Burakowski and T. Wierzchoń: Surface engineering of metals. CRC-Press 1999;
- L. Pawlowski: The science and engineering of thermal spray coatings. John Wiley & Sons 2008;
- J.R. Davies ed.: Handbook of thermal spray technology. ASM International 2004;
- J.E. Lancaster: Metallurgy of welding. Abignon Publishing, Cambridge 1999;
- G. Stachowiak, A. Batchelor, Engineering Tribology, Elsevier 2005; ASM Handbook Volume 5: Surface Engineering, ASM International, 1994.
- Selected online journals accessible via Lublin University of Technology.

TEACHING METHODS: Theoretical lecture and case studies presentation. Practical investigations, group work and reporting, individual investigation and experimentation, case studies analysis.

ASSESSMENT METHODS: Exam and student reports acceptance.

TEACHER: **Mirosław Szala, PhD Eng.**, m.szala@pollub.pl

# Fundamentals of Metrology – M74 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 15h + Laboratory 30h | ECTS: 4 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Mathematics and physics – basics.

CONTENTS:

Introduction to metrology. Tasks and division of metrology. Legal basis of metrology. Basic metrological concepts. International System of Units SI. ISO System of limits and fits. Fundamentals of statistic and error analysis - classification of error. Classification of measuring tools. Roughness, waviness and primary profile. Inspection of dimensional and geometrical deviations - measurement uncertainty. Introduction to coordinate measurements and 3D scanning. The concept of measurement system, its classification and basic definitions.

EFFECTS OF EDUCATION PROCESS:

Student knows: the types of measurement methods; System of Units SI; basic concepts in metrology; principles of developing and interpreting measurement results; metrological parameters of basic measuring tools. Student can: analyse the measuring process; elaborate measurement strategy; select appropriate measurement method; interpret measurement results.

LITERATURE:

- Raghavendra N.V., Krishnamurthy L. Engineering Metrology and Measurements, Oxford University Press, 2013.
- Mekid S. Metrology and Instrumentation: Practical Applications for Engineering and Manufacturing, John Wiley & Sons, 2021.
- Hudson S. The Metrology Handbook, States Academic Press, 2022.
- He L., Feng B. Fundamentals of Measurement and Signal Analysis, Springer, Berlin, 2022.
- Journals on-line

TEACHING METHODS: Multimedia lecture, discussion based on the student's presentations; Laboratory – practical metrological experiments.

ASSESSMENT METHODS: Lecture – final exam. Laboratory – assessment of student's reports.

TEACHER: **Mariusz Kłonica, PhD Eng.**, m.klonica@pollub.pl, Magdalena Zawada -Michałowska, PhD Eng., m.michalowska@pollub.pl, Sylwester Samborski, PhD Eng., s.samborski@pollub.pl

# Automotive Aerodynamics – M75 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: No additional requirements.

CONTENTS:

Lecture: Aerodynamics basics, Basic concepts and definitions in the field of aerodynamics, History of vehicle aerodynamics, Introduction to automotive aerodynamics, Selected topics in flow mechanics, Areas of application of aerodynamics in vehicle design, Computer systems for supporting aerodynamics modelling, Computational mesh, boundary layer and its importance, Modelling of land vehicles, Methodology of modelling vehicle aerodynamics, Forces acting on a vehicle, Passenger car aerodynamics, Commercial vehicle aerodynamics, Sports car aerodynamics, Body-mounted accessories, aerodynamic aspects of safety, Aerodynamic aspects of comfort, Internal flows, Engine cooling, Aerodynamics and noise, Bench testing of automotive aerodynamics, Computer-aided testing of automotive aerodynamic.

Laboratory: Introduction in Catia v5 software environment, Introduction in ANSYS Fluent software environment, Construction of a solid model, Modifying the shape of a car, Designing the aerodynamics of a car body using CFD, Designing the aerodynamics of additional body elements, Construction of a computational mesh, Solver settings, Performing and monitoring calculations, Presentation and analysis of results, Modelling of car body flow, Wind tunnel flow tests.

EFFECTS OF EDUCATION PROCESS:

Demonstrates knowledge of vehicle modelling and design, taking into account aerodynamics; Is able to use analytical and experimental methods, including measurements and computer simulations, to formulate and solve aerodynamic problems, interpret the obtained results, and draw conclusions; Knows the basic principles and corresponding functions of automotive aerodynamics modelling in CFD systems; Knows the principles of creating automotive aerodynamics designs; Is able to use a CFD system to build and verify a computational model of automotive aerodynamics; Is able to use computer simulations to formulate and solve aerodynamic problems, including computer simulations. Interpret the obtained results, and draw conclusions.

LITERATURE:

- Jaecheol Koh: CATIA V5 Design Fundamentals - 2nd Edition: A Step by Step Guide;
- Yunus A. Cengel, Michael A. Boles - Thermodynamics. An Engineering Approach 3rd ed., McGraw Hill 1998;
- Wolf -Heinrich Hucho, AERODYNAMICS OF ROAD VEHICLES, 1993;
- Joseph Katz, AUTOMOTIVE AERODYNAMICS, 2016.

TEACHING METHODS: Multimedia lecture, Computer laboratories – practical experiments in Catia v5 and ANSYS Fluent, Wind tunnel tests.

ASSESSMENT METHODS: Project presentation from lecture, Project documentation from laboratory.

TEACHER: **Paweł Magryta, PhD Eng.**, p.magryta@pollub.pl, Konrad Pietrykowski, PhD Eng., k.pietrykowski@pollub.pl

# Polymer Engineering – M76 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge about structure and properties of engineering materials.

CONTENTS:

Lecture: Introduction and overview of polymer materials. Classifications of polymer materials. Polymerisation, structure and properties of polymers. Thermosets and Themoplastics. Preparation, types, properties and applications of the main polymer materials (polyolefins, PVC, PS, PC, PMMA, biopolymers). Thermal Transitions. Additives (Anti Counterfieting, Antimicrobials / Biostabilisers, Antioxidants, Antistatic Agents, Biodegradable Plasticiser, Blowing Agents, Colorants, Lubricants, Fillers, Flame Retardants, Fragrances, Heat Stabilisers, Impact Modifiers, Light Stabilisers, Pigments, Plasticisers, Process Aids, Reinforcements). Polymer composites. Testing methods of polymers properties and structure. Characterisation of polymer processing methods and its varieties (extrusion, blown film extrusion, injection moulding, pressing, thermoforming, rotational moulding, metallisation, welding, casting). Machines and tools for polymer processing. Plasticizing units. Processing parameters. Auxiliary devices. Technological lines for polymer processing.

Laboratory: Determination of plastics hardness in glassy and high-elastic state (ball indentation and Shore method). Determination of impact resistance. Determination of plastics density. Determination of bending strength. Determination of plastics tensile strength. Determination of plastics tribological properties. Determination of deflection and softening temperature of plastics. Determination of plastics morphology. Determination of Melt Flow Rate. Welding process. Pressing. Injection moulding. Blown film extrusion. Profiles extrusion. Rotational moulding. 3D printing.

EFFECTS OF EDUCATION PROCESS:

Acquire basic knowledge about methods of polymer testing and the construction and operation of instruments and measuring tools. Acquire basic knowledge about methods of polymer processing and the construction and operation of machines and processing tools Preparing students for the correct application of testing and processing methods in the engineering work and practical knowledge of selected methods of polymer materials testing and of plastics processing.

LITERATURE:

- Garbacz T.: Research methods of polymer materials. Workbook. Lublin 2014;
- Sabu T., Yang W.: Advances in polymer processing. Woodhead Publishing, Boca Raton CRC Press, Oxford 2009.

TEACHING METHODS: Lectures with presentations. Laboratory classes - demonstrations of selected machines, tools and equipment with explanations and descriptions.

ASSESSMENT METHODS: Lecture: preparation and presentation od individual project. Laboratory: individual reports.

TEACHER: **Aneta Tor-Świątek, PhD Eng.**, a.tor@pollub.pl, Anna Jakimińska, PhD, a.jakiminska@pollub.pl

# Advanced Solar Thermal Engineering – M77 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Project |
| NUMBER OF HOURS: Lecture 15h + Project 15h | ECTS: 3 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate/ master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

| |
|---|
| PRELIMINARY REQUIREMENTS: None |
| CONTENTS:<br>A comprehensive short course designed to introduce participants to the physics of solar radiation, the mechanics of solar collectors, and the engineering required to design efficient solar thermal systems. Difference between thermal collector and PV collector; Different solar collector types and their efficiency; Modeling the geometry of collector for CFD analysis; Implementing the Solar collector in Ansys Fluent at a simulated workplace; Improving thermal performance in a simulated collector; Fluid flow velocity analysis inside the collector; Validation of CFD results. |
| EFFECTS OF EDUCATION PROCESS:<br>A fundamental understanding of solar collector technologies and their relative efficiencies is established through these classes. Proficiency is developed in the geometric modelling and CFD simulation of thermal systems using the Solar collector Model in ANSYS Fluent. |
| LITERATURE:<br>• |
| TEACHING METHODS: Work in groups. Work with computer. Case studies. |
| ASSESSMENT METHODS: Reports on performed laboratory exercises. |
| TEACHER: **Arkadiusz Gola, PhD Eng.**, a.gola@pollub.pl, Michał Jan Gęca PhD Eng., m.geca@pollub.pl, Ghizlene Boussouar, e4097@pollub.edu.pl |

# Physicochemistry of Materials – M78 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate / master |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Basic knowledge of chemistry, physics, structure and properties of materials.

CONTENTS:

Introducing the chemistry and physics of materials; Methods of materials identification; Physicochemical properties and methods of physicochemical characterization of materials; Structure-properties relationship of materials. Strength, tensile strength, plasticity, hardness, colour, conductivity, density, optical properties, etc. Solubility of materials and pH of solutions. Absorption of water and humidity; Thermal properties of materials and flammability. Heat capacity, phase and state changes, heat-induced degradation; Rheological properties of materials - viscosity. Surface tension; Surface properties of the materials. Adhesion, wettability, surface free energy; Engineering of blends and composite materials. Synthesis of functional materials.

EFFECTS OF EDUCATION PROCESS:

Acquire knowledge about methods of physicochemical materials characterization and using laboratory devices. Preparation of the students for the correct application of the method to the certain kind of materials. Development of laboratory skills.

LITERATURE:

- K. J. Laidler – The world of physical chemistry, Oxford University Press, 1995 ISBN: 978-01-9855-919-1;
- R. Mortimer – Physical chemistry, Academic Press, 2000 ISBN: 978-0-12-508345-4.

TEACHING METHODS: Lectures with multimedia presentations. Laboratory classes - demonstrations of selected instruments and performance of measurements with instructions and explanations.

ASSESSMENT METHODS: Lectures – exam, Laboratory classes – presence, reports.

TEACHER: **Anna Jakimińska, PhD**, a.jakiminska@pollub.pl, Aneta Tor-Świątek, PhD Eng., a.tor@pollub.pl

# Aerodynamics and Flight Mechanics of UAVs – M79 ❄ ☼

| | |
|---|---|
| FACULTY: Faculty of Mechanical Engineering | CLASS TYPE: Lecture, Laboratory |
| NUMBER OF HOURS: Lecture 30h + Laboratory 30h | ECTS: 5 |
| SEMESTER: winter or summer | CLASS LEVEL: undergraduate |
| LANGUAGE OF INSTRUCTION: English | MINIMAL NUMBER OF STUDENTS: 6 |

PRELIMINARY REQUIREMENTS: Fundamentals of analysis, partial and ordinary differential equations; fluid mechanics, physics – basic laws.

CONTENTS:
Cross-section of the wing (aerodynamic profile). Basic geometric parameters of the profile. Basic parameters of the wing. The principle of operation of devices that increase wing load capacity. The impact of wing mechanization on aerodynamic characteristics. The impact of wing mechanization on UAV aircraft flight characteristics. The speed of sound propagation in different media and factors affecting it. Mach number, critical Mach number. Reference systems. Spatial position parameters. Degrees of freedom in helicopter motion. Types and parameters of helicopter motion. Balancing a single-rotor UAV helicopter. Forces and moments acting on a single-rotor UAV helicopter with a tail rotor. UAV helicopter balance and its types.

EFFECTS OF EDUCATION PROCESS:
knowledge of helicopter balance in horizontal flight and the power required for horizontal flight. The relationship between the pitch of the main rotor and tail rotor and horizontal flight speed. UAV power requirement and available power curves. UAV horizontal flight speed ranges. Limitations on maximum UAV horizontal flight speed. Ways to increase maximum UAV horizontal flight speed. Effect of atmospheric conditions on UAV horizontal flight speed. Range and endurance of UAV horizontal flight. The effect of wind on the stability of a helicopter UAV in horizontal flight. The effect of the mass balance of a helicopter UAV on its stability, controllability, and speed in horizontal flight.

LITERATURE:

- Warren F. Phillips, Aerodynamics of Wings, R. P. G. Collinson, Aerodynamics and Aircraft Control, Emanuele Rizzo, Aldo Frediani, Application of Optimisation Algorithms to Aircraft Aerodynamics

TEACHING METHODS: Introduction presentation/lecture, hands-on demonstrations/practical laboratories, group or individual project.

ASSESSMENT METHODS: Mark for the presentation of the completed project.

TEACHER: **Tomasz Łusiak, PhD Eng.**, t.lusiak@pollub.pl