S Y L L A B U S

Course description

Course code	Course	Modelowanie numeryczne w mechanice FEM+CFD+FSI
ME/O/I/NST/*B19*		Simulations in Mechanics FEM+CFD+FSI
Language of instruction	English	
Academic year	2025/2026	

field of study:	Mechanical Engineering
field of specialisation:	All
Educational level	first-cycle studies
Education profile	General academic
Mode of study	Part-time studies
Semester(s)	5,6,7

Affiliation with a group of classes	B . Group of obligatory course core subject		
Course status	Obligatory		
Types of classes, instruction hours, ECTS credits	Types of classes	Number of instruction hours	Number of ECTS credits
	Lecture	24[h]	9ECTS
	Classes	0[h]	
	Lab	48[h]	

Linkage of the course	with the education profile	Related to the conducted scientific activity in the discipline to which the field of study is assigned	9ECTS
	with qualifications	It is used to acquire engineering competences by the student	9 ECTS
	with science discipline	Mechanical engineering	9ECTS
Form of teaching	Traditional – classes organized at the University /classes conducted using distance learning methods and techniques		
Prerequisites	knowledge of mathematics, mechanics, fluid mechanics		

Department	Faculty of Mechanical Engineering
Coordinator	dr hab. inż. Przemysław Motyl, prof. URad.
The website of the basic organizational unit	http://wm.uniwersytetradom.pl
E-mail address, phone number of the coordinator	p.motyl@urad.edu.pl

LEARNING OUTCOMES, CURRICULUM CONTENT, TEACHING CLASSES, VERIFICATION OF LEARNING OUTCOMES

Learning Objective:	The aim of the course is to provide students with a comprehensive understanding and practical skills in applying numerical methods—primarily the finite element method (FEM), the finite

	volume method (FVM), and computational fluid dynamics (CFD)—to solve problems in structural mechanics, fluid mechanics, and fluid-structure interaction (FSI). Students will learn the theoretical foundations of FEM through analysis of bar structures, perform linear and non-linear static, thermal, and modal analyses, and acquire the ability to model and simulate coupled mechanical and fluid systems. The course emphasizes the use of modern computational tools for solving complex engineering problems involving solid and fluid domains, as well as their mutual interactions.
Curriculum Content:	The course integrates theoretical foundations with applied computational methods in mechanics, focusing on the finite element method (FEM), computational fluid dynamics (CFD), and fluid-structure interaction (FSI). The content of the course is aligned with current scientific research and reflects state-of-the-art developments in numerical simulations of mechanical systems. Lectures: Fundamentals of the finite element method (FEM): discretization principles, shape functions, stiffness matrices, boundary conditions, equilibrium and compatibility. Types and properties of finite elements: 1D (bar, beam), 2D (plane stress, plane strain), and 3D elements. FEM applications in structural mechanics: trusses, beams, frames. Formulation of global stiffness matrices and coordinate transformations. Modeling errors and sources of numerical inaccuracy in FEM. Advanced FEM topics: linear vs. non-linear analysis, modal analysis, stress-thermal coupling, and contact problems. Introduction to fluid mechanics: conservation equations (mass, momentum, energy), laminar and turbulent flows. Turbulence modeling and discretization techniques in CFD (FVM approach). Solving Navier–Stokes equations for incompressible flows, with focus on stability, convergence, and validation. Fundamentals of fluid-structure interaction (FSI): dimensional analysis, coupling regimes (weak and strong), slow vs. fast flow coupling, mono- and bidirectional coupling strategies. Overview and comparison of commercial and open-source software environments: ANSYS (Mechanical, Fluent), Autodesk CFD, OpenFOAM. Laboratory: Practical use of FEM software for structural analysis of trusses, beams, and frames in both linear and non-linear regimes. Discretization of models using structured and unstructured 2D/3D meshes; mesh generation techniques. Application of various FEM-based solvers for stress, thermal, and modal analyses.

	Comparative simulations using different finite element types and mesh resolutions. Execution of CFD simulations using FVM-based tools (OpenFOAM, Fluent, Autodesk CFD). Programming and customizing simulation tasks in C++ within OpenFOAM environment. Performing FSI simulations with one- and two-way coupling approaches, with validation of numerical results. Analysis of convergence, mesh independence, and numerical accuracy in coupled simulations.
Didactic (educational) methods:	feeding methods (information lecture, lecture, reading), problem methods (problem lecture, conversational lecture), activating method
Course assessment type, the criteria for assessing the achieved learning outcomes, and the method of calculating the final grade:	The condition for passing the course *Simulations in Mechanics FEM+CFD+FSI* is the achievement of all defined learning outcomes. This includes obtaining passing grades from laboratory reports and the final examination (written or oral). Active participation in laboratory sessions and the completion of all assigned computational tasks and reports are mandatory. A minimum of 50% of the total available points is required to pass the course. Additionally, students must demonstrate the ability to apply theoretical knowledge in the practical implementation of numerical methods—particularly FEM, CFD, and FVM—to solve engineering problems in structural mechanics, fluid mechanics, and fluid-structure interaction.

Learning outcomes for the course in relation to the field of study learning outcomes and the type of classes				Methods of verifying learning outcomes	
Learning outcome number	Description of the learning outcomes for the course (PEU) A student who has passed the course (**W**) knows and understands / (**U**) can / (**K**) is ready to:	Field of study learning outcome (KEU)	Types of classes	Form of verification (credits)	Methods of testing and assessment
W1	Has knowledge of the theoretical foundations of the Finite Element Method (FEM), Computational Fluid Dynamics (CFD), and Fluid-Structure Interaction (FSI), and their application to the modeling and simulation of mechanical systems.	K_WG04, K_WG17, K_WG16	Lecture	Credit with grade	Written test (evaluation test)
U1	Is able to perform strength and fluid dynamic analyses of mechanical systems (e.g., trusses, beams, frames, and fluid domains) using FEM and CFD methods; uses computer software implementing FEM/CFD/FSI algorithms.	K_UW02, K_UW05, K_UW13	Exercises Laboratories	Credit with grade	Written test, assessment of laboratory reports, observation during classes
U2	Can select appropriate numerical models and simulation techniques (e.g., FEM, CFD, FSI) from commercial software packages and apply them for engineering analysis; is able to interpret the obtained results critically.	K_UW05, K_UW13	Exercises Laboratories	Credit with grade	Laboratory reports, practical performance during laboratory sessions, oral test
K1	Is willing to comprehensively analyze and effectively carry out assigned tasks, work in a team, and take responsibility	K_KK02	Exercises Laboratories	Credit (pass/fail or grade,	Observation of teamwork, participation during exercises,

	for the results of group work in engineering design and analysis projects.			depending on system)	verbal assessment

Literature and teaching aids
Primary literature: 1. Zienkiewicz O. C., Taylor R. L., The Finite Element Method , I: The Basis, Butterworth-Heinemann, Oxford, 2000. 2. Jean-François Sigrist, Fluid-Structure Interaction: An Introduction to Finite Element Coupling, ISBN:9781119952275, DOI:10.1002/9781118927762, Copyright © 2015 John Wiley & Sons, Ltd 3. John D. Anderson Jr., Computational Fluid Dynamics, McGraw-Hill Higher Education , ISBN-13: 978-0070016859 4. Joel H. Ferziger, Milovan Peric, Computational Methods for Fluid Dynamics, Springer Berlin Heidelberg, ISBN-10: 354042074 5. John D. Anderson Jr., Computational Fluid Dynamics, McGraw-Hill Higher Education , ISBN-13: 978-0070016859 6. Joel H. Ferziger, Milovan Peric, Computational Methods for Fluid Dynamics, Springer Berlin Heidelberg, ISBN-10: 3540420746 Study aids: To support students' learning process, the following materials and tools are made available: • Lecture slides and detailed handouts • Sample problems with solutions for self-study • Access to laboratory manuals and experiment instructions

Student workload required to achieve the assumed learning outcomes – the balance of ECTS credits		
Attendance, participation	Student workload [h].	
	Student's self-study hours Classes without a teacher (ZBN)	Classes
Participation in lectures/classes/lab	X	24/0/48[h]
Preparation for lectures/classes/lab , Preparation for ... credit / exam	70/0/125 [h]	X
Total student workload Preparation for ... credit / exam	195[h]/ 6,5 ECTS	72 [h]/ 2,5 ECTS
ECTS points per subject	9 ECTS	

Additional information, comments
In the case of students with special needs, including disabilities, and chronic illnesses, the methods and forms of verification of learning outcomes specified above (in the syllabus) are adapted to the individual needs of these students, as appropriate. Detailed rules and forms of support for students with special needs, including those with disabilities and chronically ill, during classes, credits, and exams are specified in: University Regulations (Regulamin Studiów Uniwersytetu Technologiczno-Humanistycznego w Radomiu), Study Regulations (Zasady Studiowania), and Procedure for Ensuring Accessibility of the Educational Process to Students with Special Needs, Including Those with Disabilities and Chronically ill (Procedura dotycząca zapewnienia dostępności procesu kształcenia studentom ze szczególnymi potrzebami, w tym: z niepełnosprawnością, przewlekle chorych).