GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Numerical methods in heat and fluid flow, PG_00064863		
Field of study	Mechanical Engineering		
Date of commencement of studies	February 2027	Academic year of realisation of subject	2027/2028
Education level	second-cycle studies	Subject group	Specialty subject group Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	English
Semester of study	2	ECTS credits	4.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Division of Thermal Power Systems -> Institute of Energy -> Faculty of Mechanical Engineering and Ship Technology -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Paweł Ziółkowski	
	Teachers		

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	0.0	30.0	0.0	60
	E-learning hours included: 0.0						

Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
	Number of study hours	60	6.0	34.0	100

Subject objectives	The objective of this course is to present the application of numerical methods in heat and flow processes. The theoretical component (lecture) aims to familiarize students with issues related to modeling various components of power systems, including entire thermal cycles and selected power system components, using numerical software, so that students are able to properly model the process and interpret the results. It also introduces the computational capabilities of CFD codes. The objective of the practical component (project) is for students to acquire competence in the use of numerical analysis tools for heat and flow processes.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_U15] evaluates the feasibility of advanced methods and tools for solving complex engineering tasks of a practical nature, characteristic of the field of study, and selects and applies appropriate methods and tools for this purpose	The students are able to assess the suitability of advanced methods and tools for solving a complex engineering task of a practical nature, namely he can indicate which approach is appropriate for the indicated engineering problem. The students are able to refer to the performance of individual devices, and then select and apply the appropriate methods and computational tools for this purpose.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject [SU2] Assessment of ability to analyse information
[K7_W02] demonstrates a structured and theoretically grounded knowledge of the key topics in Mechanical Engineering enabling the analysis and modelling of mechanical systems, processes and devices	The students demonstrate a structured and theoretically underpinned knowledge covering the key issues of thermal-fluid machines allowing analysis and modeling of systems and processes using numerical tools.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects
[K7_W12] identifies and interprets the main developmental trends and significant new achievements in the field of engineering and technical sciences and disciplines relevant to the course of study	The students identifie and interpret the main development trends and the most significant new developments in the field of engineering and technical sciences in terms of thermal and utility power engineering. They are able to identify modern thermal-fluid devices currently used in the power industry with the indication of methods of their modeling.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects
[K7_U11] communicates and justifies opinions on specialized topics in a manner understandable to diverse audiences, including the use of modern techniques, including information technology	Students communicate and justify their opinions on specialized topics in the field of heat and fluid flow. Students justify their modeling choices in a manner understandable to diverse audiences, including through the use of modern techniques, such as computer-based methods that rely on numerical computational tools.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools

Subject contents

Course content – lecture

Repeat the information on thermodynamic cycles and broaden the information on their modeling with the use of commercial tools. Presentation of balances, constitutive equations, the way of setting conditions in CFD codes. Regulation and control of devices in the context of heat exchangers. Presentation of capabilities of CFD code.

Course content – project

The project-based classes will focus on modeling practical examples in the context of heat and fluid flow.

Prerequisites and co-requisites

Students should be able to solve selected problems in differential and integral calculus. They should be familiar with ordinary and partial differential equations. They should have a basic understanding of fluid mechanics, solid mechanics, strength of materials and thermodynamics.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Written exam	56.0%	60.0%
Project - evaluation of the progress of the topic and the final results obtained, such as presenting them in a presentation or report	56.0%	40.0%

Recommended reading

Basic literature

Stephen Turns: Thermal-Fluid Sciences an integrated approach. Cambrige University Press, New York 2006.

Ziółkowski, P.; Radomski, P.; Koulali, A.; Kreft, D.; Barański, J.; Mikielewicz, D. Numerical Study of Heat Transfer Intensification in a Chamber with Heat Generating by Irradiated Gold Nanorods: One-Way Multiphysics and Multiscale Approach. Energies 2026, 19, 181. https://doi.org/10.3390/en19010181

Ziółkowski, Learning materials from E-nauczanie webpage. Gdańsk 2026.

	Supplementary literature	F. M. White - Fluid Mechanics, McGraw-Hill, 2011 Wolfgang Altmann: Practical process control for engineers and technicians. Newnes, Oxford 2005. Rolf Kehlhofer: Combined-cycle gas & steam turbine power plant. The Fairmont Press, Lilburn, 1991.
	eResources addresses	

Example issues/ example questions/ tasks being completed	1) Using/drawing a diagram of a channel with one inlet and one outlet, transition from the general differential form of the 3D mass balance to the 0D approach under steady-state conditions. Describe the variables appearing in the equations. (3 points) 2) Using/drawing a diagram of a channel with one inlet and one outlet, transition from the general differential form of the 3D momentum balance to the 0D approach under steady-state conditions. Describe the variables appearing in the equations. (3 points) 3) Using/drawing a diagram of a channel with one inlet and one outlet, as well as a heating wall and a moving blade, derive the 0D steady-state solution from the general 3D differential form of the energy balance equation. Describe the variables appearing in the equations. (3 points) 4) A diagram of the Rankine cycle and p-v, T-s, and h-s graphs, along with equations describing the transformations in the successive devices, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the diagram of the devices—the equations modeling the physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices.) (3 points) 5) A diagram of the Joule–Brayton cycle, along with p-v, T-s, and h-s diagrams, including the equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the device diagram—the equations modeling physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices) (3 points) 6) A flow diagram of a dry-medium ORC cycle, along with p-v, T-s, and h-s diagrams, including the equations describing the transformations in the successive components, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all diagrams and on the equipment schematic—the equations modeling physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices). (3 points) 7) A schematic of a combined cycle system with a single-wall boiler, along with T-s, h-s, and T-Q graphs showing the temperature distribution along the flue gas path, including equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the equipment diagram—the equations modeling the physical phenomena should correspond to the mathematical models of the phenomena occurring in the given equipment.) (3 points) 8) A diagram of a counter-current cycle (Linde cycle) and the p-h, T-s, and T-Q graphs showing the temperature distribution in the heat exchangers on both sides of the exchangers, along with equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (Mark characteristic points on all graphs and on the device diagram—the equations modeling the physical phenomena should correspond to the mathematical models of the phenomena occurring in the given devices). (3 points) 9) A diagram of the Carnot cycle, along with p-v and T-s graphs, including equations describing the transformations in each device, distinguishing between mass, momentum, and energy balances. (3 points) 10) Diagram of the computational domain with boundary conditions for wind energy extraction. The fundamental CFD equation corresponding to the general mathematical model of this phenomenon. (2 points) 11) An example of a hybrid system, such as a photovoltaic farm or a wind farm combined with a cycle leading to energy storage (CAES), including a system diagram and a description of how the individual devices interact. Provide the definitions of the equations determining the system's efficiency. (2 points) 12) An example of an ORC-VCC hybrid system with a thermal cycle plotted on p-h and T-s diagrams, including a system diagram and a description of how the individual components interact. Equations defining the system's efficiency. (2 points) 13) Draw a diagram illustrating the relationship between conservative and kinematic variables, fluxes, and sources used in thermomechanics (including CFD). (3 points) 14) List examples of constitutive equations characteristic of liquids, gases, and solids. Describe one example for each, specifying all variables, particularly material constants. (3 points)

	15) Discuss the four branches of Computational Thermomechanics of the Continuum. Describe the relationships between these branches using an appropriate diagram as an example. (2 points) 16) Describe the conservative form of the mass balance (equation and variables). Point out the differences between the 0D and 3D mass balances. (2 points) 17) Describe the conservative form of the momentum balance (equation and variables). Identify the differences between the 0D and 3D balances. (2 points) 18) Describe the conservative form of the energy balance (equation and variables). Identify the differences between the 0D and 3D balances. (2 points) 19) Describe the basic k-omega or k-epsilon turbulence evolution equations. Identify their analogies in the system of conservative equations with respect to the momentum balance. Discuss the sources of turbulence and the processes associated with this phenomenon. (3 points) 20) Provide an example of energy storage in a thermodynamic cycle diagram (e.g., a cycle with a steam reservoir) along with the equations describing this phenomenon—in either 3D or 0D. (2 points)
Practical activites within the subject	Not applicable

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