GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Advanced numerical fluid mechanics, PG_00062673					
Field of study	Naval Architecture and Offshore Structures					
Date of commencement of studies	February 2024		Academic year of realisation of subject		2024/2025	
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		Polish	
Semester of study	2		ECTS credits		5.0	
Learning profile	general academic profile		Assessment form		assessment	
Conducting unit	Institute of Ocean Engineering and Ship Technology -> Faculty of Mechanical Engineering and Ship Technology					
Name and surname of lecturer (lecturers)	Subject supervisor		dr hab. inż. Paweł Dymarski			
	Teachers					
Lesson types and methods of instruction	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	0.0	45.0	0.0	75
	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	75		10.0	40.0	125
Subject objectives	The aim of the course is to familiarize students with the methods of numerical fluid mechanics. Both methods used to model potential flow and RANSE-CFD methods based on the finite volume method will be discussed. During laboratory classes, students will learn to prepare computational tasks, perform calculations and analyze the obtained results. In particular, students will learn how to perform flow calculations with a free surface.					

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K7_U01] Develops innovative strategies to solve complex and dynamic problems by synthesizing information from various sources and utilizing analytical, simulation, and experimental methods, considering environmental variability	The student is able to build computational grids and set boundary conditions to solve problems in the field of fluid and gas dynamics using CFD software.	[SU1] Assessment of task fulfilment [SU3] Assessment of ability to use knowledge gained from the subject [SU4] Assessment of ability to use methods and tools
	[K7_W02] Explains the essence and relationships of key components describing systems and processes in ocean engineering, utilizing current knowledge from major scientific fields related to the field of study	The student is able to apply methods of computational fluid mechanics to solve problems in the field of ocean engineering.	[SW3] Assessment of knowledge contained in written work and projects
	[K7_W06] Capable of finding and utilizing credible sources of information crucial for analyzing issues within the field of study	The student is able to use software textbooks, examples and other sources to independently analyze CFD problems.	[SW3] Assessment of knowledge contained in written work and projects
	[K7_U02] Presents convincing and logically justified arguments regarding outcomes through critical analysis of information in diverse technical contexts and an approach to their interpretation	The student will acquire basic skills in analyzing the results of CFD calculations. He can analyze the velocity field and pressure field. Recognizes when results are consistent.	[SU2] Assessment of ability to analyse information [SU4] Assessment of ability to use methods and tools [SU1] Assessment of task fulfilment
	[K7_W03] Demonstrates advanced skills in applying analytical methods and problem-solving techniques related to ocean engineering, using appropriate tools	Possesses and applies skills in the field of numerical fluid dynamics to solve hydromechanical problems in ocean engineering	[SW3] Assessment of knowledge contained in written work and projects
	[K7_K01] Understands the need for lifelong learning, critically evaluate acquired knowledge, and comprehend the significance of knowledge in addressing cognitive and practical problems	The student will acquire the ability to solve practical problems in the field of fluid mechanics using CFD tools	[SK3] Assessment of ability to organize work [SK5] Assessment of ability to solve problems that arise in practice

Subject contents	1. Basic equations governing the movement of fluids 1.1 Basic (simplified) mathematical models used in FM - incompressible fluids - non-viscous liquids - potential flows 2. Introduction to numerical methods 2.1 What is CFD 2.2 Classification of methods - methods of solving potential flows - methods for solving viscous flows: -- finite CD method, -- FVM finite volume method, 3. Methods of modeling potential flows 3.1 Laplace's equation 3.2 Formulating boundary conditions: - Neumann problem, - Dirichlet problem. 3.3 Functions satisfying Laplace's equation - hydromechanical singularities 3.3.1 Modeling simple flows using hydrodynamic singularities - Rankin oval, - flow around a circular cylinder, - flow around the sphere 3.4 General method for determining potential non-circulating flows - source-sink method 3.5 Methods for determining the flow on a hydromechanical sheet - circulation flows - 2D flows, Kutta condition, - vortex fiber in 3D space - Biot-Savart equation, - flow around an airfoil with a finite span 3.6 Hydrodynamic reactions in stationary potential flow. Discussion 3.7 Unstationary potential flow 3.7.1 Water wave motion potential 3.7.2 Flow around bodies in wave motion 3.7.3 Bernoulli equation. Determination of the hydrodynamic reaction 4. Methods for determining viscous flows. Finite volume method 4.1 Definition of mesh element (CV control volume) 4.2 Surface and volume integrals within CV 4.3 Interpolation schemes and their impact on the accuracy/stability of calculations 4.4 Formulating boundary conditions 5. Computational grids 5.1 Types of computational grids and their impact on calculation accuracy 5.2 Techniques for "thickening" the mesh. Why do we use different densities? 5.2.1 Mesh refinement near the "wall". Problem y+ 5.3 Special/non-standard nets 5.3.1 non-machining grid 5.3.2 Moving grids: - sliding mesh - "overset" mesh (overlapping meshes) 5.4. Examples of "good" and "bad" mesh. 5.5. Analysis of the influence of mesh density on the solution 6. Techniques used to solve systems of linear and nonlinear equations 6.1 Exact methods 6.2 Iterative methods. The problem of "empty" matrices 6.3 Systems of nonlinear equations. 7. Methods used for non-stationary calculations 7.1 Discussion of "basic" time integration methods - Euler methods (explicit and implicit) - trapezoidal method - midpoint method 7.2 Predictor-corrector integration methods 7.3. Runge-Kutta methods and others 7.4. The impact of the methods used on the accuracy/stability and speed of the obtained solution. 8. (optional) Issues related to solving the N-S equation 9. Turbulence models 10. Special and practical issues 10.1 Testing the convergence of calculations 10.2 Calculation of the hydrodynamic reaction 10.3 Calculation of object dynamics - fluid-rigid body interaction 10.4 Boundary conditions for calculations of a ship/object subjected to wave action 10.5 Hull-propeller systems.

Prerequisites and co-requisites	Knowledge of fluid mechanics, Knowledge of the basics of numerical methods: - the concept of interpolation, - basics of numerical integration Knowledge of 3D object modeling software, Knowledge of basic mechanics: - understanding the concept of reaction force, understanding the second law of dynamics, - knowledge of vector calculus
Assessment methods and criteria	see table below

Subject passing criteria	Passing threshold	Percentage of the final grade
Lecture	60.0%	50.0%
Project	70.0%	50.0%

Recommended reading	Basic literature	Ferziger J.H., Perić M. Computational Methods for Fluid Dynamics. Springer 2002 Gryboś Ryszard: Podstawy mechaniki płynów. Wydawnictwo Naukowe PWN 1998 John D. Anderson: Fundamentals of Aerodynamics. Mc Graw Hill 2011
	Supplementary literature	H K Versteeg and W Malalasekera: An Introduction to Computational Fluid Dynamics. Pearson Education Limited 2007 O.M. Faltinsen: Sea Loads On Ships and Offshore Structures . Cambridge 1990 M. Krężelewski: Hydromechanika ogólna i okrętowa część II. Skrypt PG
	eResources addresses	Adresy na platformie eNauczanie:
Example issues/ example questions/ tasks being completed		
Work placement	Not applicable	