



## Subject card

|   |   |  |   |                                     |   |            |     |
|---|---|--|---|-------------------------------------|---|------------|-----|
| Subject name and code                       | Advanced numerical fluid mechanics, PG_00065626   |  |   |                                     |   |            |     |
| Field of study                              | Naval Architecture and Offshore Structures  |  |   |                                     |   |            |     |
| Date of commencement of studies             | February 2025   |  | Academic year of realisation of subject |                                     | 2025/2026   |            |     |
| Education level                             | second-cycle studies  |  | Subject group                           |                                     | Specialty subject group<br>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                         |                                     | exam  |            |     |
| Conducting unit                             | Institute of Naval Architecture -> Faculty of Mechanical Engineering and Ship Technology -> Wydział Politechniki Gdańskiej  |  |   |                                     |   |            |     |
| 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   |   | 12.0                                |   | 38.0       | 125 |
| Subject objectives                          | <p>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.</p> <p>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.</p> |  |   |                                     |   |            |     |

| Learning outcomes | Course outcome   | Subject outcome  | Method of verification  |
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|                   | [K7_W01] explains and describes, based on general knowledge in the field of scientific disciplines forming the theoretical foundations of Naval Architecture and Ocean Engineering, the construction and principles of operation of marine systems, processes and their components, as well as methods and means of their design and operation | The student is able to use the learned CFD methods and tools to analyze the operation of ship and ocean engineering system elements. Is able to apply CFD methods as design methods  | [SW3] Assessment of knowledge contained in written work and projects  |
|                   | [K7_U02] formulates and tests hypotheses concerning problems related to shipborne and offshore systems/processes, as well as simple research problems  | The student is able to formulate a computational task (computational problem) based on the data provided (in the form of description and/or documentation)   | [SU4] Assessment of ability to use methods and tools<br>[SU1] Assessment of task fulfilment<br>[SU2] Assessment of ability to analyse information                   |
|                   | [K7_U01] applies acquired analytical, simulation, and experimental methods, as well as mathematical models for analysis and evaluation of shipborne and offshore systems and processes   | The student is able to use the analytical and numerical methods learned to model and analyze issues related to ship hydromechanics and offshore structures   | [SU3] Assessment of ability to use knowledge gained from the subject<br>[SU4] Assessment of ability to use methods and tools<br>[SU1] Assessment of task fulfilment |
|                   | [K7_U04] creatively designs or modifies, either entirely or in part, a shipborne or offshore system or process according to a given specification, considering both technical and non-technical aspects, estimating costs and adopting design techniques representative for the field  | The student is able to use the acquired knowledge of numerical fluid mechanics (CFD) to solve design problems in the field of ship hydrodynamics and ocean engineering. The student is able to (preliminarily) estimate the workload of a given task/problem | [SU3] Assessment of ability to use knowledge gained from the subject<br>[SU1] Assessment of task fulfilment<br>[SU4] Assessment of ability to use methods and tools |
|                   | [K7_U13] evaluates the feasibility and potential for utilizing new technical and technological achievements in accomplishing tasks characteristic for the field of study   | The student assesses the usefulness and possibility of using the computational methods learned in the implementation of tasks related to the hydromechanics of ships and offshore structures.  | [SU2] Assessment of ability to analyse information  |
|                   | [K7_W04] demonstrates knowledge encompassing selected issues in the field of advanced knowledge, particularly in the scope of methods, techniques, tools, and algorithms specific to Naval Architecture and Ocean Engineering  | The student demonstrates knowledge covering selected issues in the field of advanced fluid mechanics, in particular in the context of ship hydromechanics and offshore facilities.   | [SW3] Assessment of knowledge contained in written work and projects  |

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| Subject contents | <ol style="list-style-type: none"> <li>1. Basic equations governing the movement of fluids <ol style="list-style-type: none"> <li>1.1 Basic (simplified) mathematical models used in FM <ul style="list-style-type: none"> <li>- incompressible fluids</li> <li>- non-viscous liquids</li> <li>- potential flows</li> </ul> </li> </ol> </li> <li>2. Introduction to numerical methods <ol style="list-style-type: none"> <li>2.1 What is CFD</li> <li>2.2 Classification of methods <ul style="list-style-type: none"> <li>- methods of solving potential flows</li> <li>- methods for solving viscous flows: <ul style="list-style-type: none"> <li>-- finite CD method,</li> <li>-- FVM finite volume method,</li> </ul> </li> </ul> </li> </ol> </li> <li>3. Methods of modeling potential flows <ol style="list-style-type: none"> <li>3.1 Laplace's equation</li> <li>3.2 Formulating boundary conditions: <ul style="list-style-type: none"> <li>- Neumann problem,</li> <li>- Dirichlet problem.</li> </ul> </li> <li>3.3 Functions satisfying Laplace's equation - hydromechanical singularities <ol style="list-style-type: none"> <li>3.3.1 Modeling simple flows using hydrodynamic singularities <ul style="list-style-type: none"> <li>- Rankin oval,</li> <li>- flow around a circular cylinder,</li> <li>- flow around the sphere</li> </ul> </li> </ol> </li> <li>3.4 General method for determining potential non-circulating flows <ul style="list-style-type: none"> <li>- source-sink method</li> </ul> </li> <li>3.5 Methods for determining the flow on a hydromechanical sheet - circulation flows <ul style="list-style-type: none"> <li>- 2D flows, Kutta condition,</li> <li>- vortex fiber in 3D space - Biot-Savart equation,</li> <li>- flow around an airfoil with a finite span</li> </ul> </li> <li>3.6 Hydrodynamic reactions in stationary potential flow. Discussion</li> <li>3.7 Unstationary potential flow <ol style="list-style-type: none"> <li>3.7.1 Water wave motion potential</li> <li>3.7.2 Flow around bodies in wave motion</li> <li>3.7.3 Bernoulli equation. Determination of the hydrodynamic reaction</li> </ol> </li> </ol> </li> <li>4. Methods for determining viscous flows. Finite volume method <ol style="list-style-type: none"> <li>4.1 Definition of mesh element (CV control volume)</li> <li>4.2 Surface and volume integrals within CV</li> <li>4.3 Interpolation schemes and their impact on the accuracy/stability of calculations</li> <li>4.4 Formulating boundary conditions</li> </ol> </li> <li>5. Computational grids <ol style="list-style-type: none"> <li>5.1 Types of computational grids and their impact on calculation accuracy</li> <li>5.2 Techniques for "thickening" the mesh. Why do we use different densities? <ol style="list-style-type: none"> <li>5.2.1 Mesh refinement near the "wall". Problem <math>y^+</math></li> </ol> </li> <li>5.3 Special/non-standard nets <ol style="list-style-type: none"> <li>5.3.1 non-machining grid</li> <li>5.3.2 Moving grids: <ul style="list-style-type: none"> <li>- sliding mesh</li> <li>- "overset" mesh (overlapping meshes)</li> </ul> </li> </ol> </li> <li>5.4. Examples of "good" and "bad" mesh.</li> <li>5.5. Analysis of the influence of mesh density on the solution</li> </ol> </li> <li>6. Techniques used to solve systems of linear and nonlinear equations <ol style="list-style-type: none"> <li>6.1 Exact methods</li> <li>6.2 Iterative methods. The problem of "empty" matrices</li> <li>6.3 Systems of nonlinear equations.</li> </ol> </li> <li>7. Methods used for non-stationary calculations <ol style="list-style-type: none"> <li>7.1 Discussion of "basic" time integration methods <ul style="list-style-type: none"> <li>- Euler methods (explicit and implicit)</li> <li>- trapezoidal method</li> <li>- midpoint method</li> </ul> </li> <li>7.2 Predictor-corrector integration methods</li> <li>7.3. Runge-Kutta methods and others</li> <li>7.4. The impact of the methods used on the accuracy/stability and speed of the obtained solution.</li> </ol> </li> <li>8. (optional) Issues related to solving the N-S equation</li> <li>9. Turbulence models</li> <li>10. Special and practical issues <ol style="list-style-type: none"> <li>10.1 Testing the convergence of calculations</li> <li>10.2 Calculation of the hydrodynamic reaction</li> <li>10.3 Calculation of object dynamics - fluid-rigid body interaction</li> <li>10.4 Boundary conditions for calculations of a ship/object subjected to wave action</li> <li>10.5 Hull-propeller systems.</li> </ol> </li> </ol> |
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| Prerequisites and co-requisites | Knowledge of fluid mechanics,<br>Knowledge of the basics of numerical methods:<br>- the concept of interpolation,<br>- basics of numerical integration<br>Knowledge of 3D object modeling software,<br>Knowledge of basic mechanics:<br>- understanding the concept of reaction force, understanding the second law of dynamics,<br>- knowledge of vector calculus |   |                               |
| Assessment methods and criteria | Subject passing criteria   | Passing threshold   | Percentage of the final grade |
|                                 | Project  | 70.0%   | 50.0%                         |
|                                 | Lecture  | 60.0%   | 50.0%                         |
| Recommended reading             | Basic literature   | Ferziger J.H., Perić M. Computational Methods for Fluid Dynamics. Springer 2002<br>Gryboś Ryszard: Podstawy mechaniki płynów. Wydawnictwo Naukowe PWN 1998<br>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<br>O.M. Faltinsen: Sea Loads On Ships and Offshore Structures . Cambridge 1990<br>M. Krężelewski: Hydromechanika ogólna i okrętowa część II. Skrypt PG |                               |
|                                 | eResources addresses   |   |                               |
|                                 | Example issues/<br>example questions/<br>tasks being completed   |   |                               |
| Work placement                  | Not applicable   |   |                               |

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