## *Computational Methods for Ordinary and Partial Differential Equations*

### *- COURSE SYLLABUS*

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| 1. | **Course title:**<br>***Computational Methods for Ordinary and Partial Differential Equations*** | |
| 2. | **Lecturers:**<br>*Dr Toktam Zand, Assistant Professor* | |
| 3. | **Field, type and level of studies, year of study:**<br>*Mathematics, Programming, all years of study* | |
| 4. | **Course character:**<br>*Monographic lecture on methods and practical application by coding the methods in MATLAB/Python* | |
| 5. | **Teaching method:**<br>*Hybrid (traditional and/or on-line)* | |
| 6. | **Language:** | *English* |
| 7. | **Course type and number of hours:**<br>*Lecture (25h); practical exercises (20h) (in total 45h: 15 x 3h)* | |
| 8. | **Estimated load of student's independent work:** | *15 h* |
| 9. | **Total workload and number of ECTS points:** | *75h, 3 ECTS* |
| 10. | **Short description and main focus of the course:**<br>*In today's world, computational techniques are essential knowledge for researchers to tackle complex problems that may be intractable analytically. This course is designed for students from all fields who need to solve ordinary or partial differential equations numerically. While our focus will be on Earth science problems, the presenting methods have broad applications,  including fluid dynamics, medical imaging, geochemistry, and climate modeling.*<br>*We will begin by exploring fundamental concepts in mathematics and continuum mechanics, providing a review on the problem which numerical methods are needed to tackle them. We will then delve into the concept of numerical methods, covering classical approaches as well as some of the most modern and efficient techniques available today.*<br>*Throughout the course, we will cover a range of numerical methods, including finite difference  methods (both classical and staggered grid), finite element method, and spectral method. For  each method, we will discuss important concepts such as stability, dispersion,* | |

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| | *discretization errors, and boundary conditions, ensuring a comprehensive understanding of their implementation and limitations.*<br>*To develop our potential knowledge to practical applications, couple of exercises will be conducted using MATLAB/Python, allowing students to apply these methods to solve geoscience equations numerically. These exercises will include solving equations such as the acoustic and elastic wave propagation, heat flow, and electromagnetic wave propagation.*<br>*By the end of this course, students will have the skills and knowledge to confidently apply numerical methods to tackle complex problems in Earth sciences and modelling the physical procedures.* |
| **11.** | **References:**<br>• *Becker, T. W. and Kaus, B. J. P., Numerical Modeling of Earth Systems: An introduction to computational methods with focus on solid Earth applications of continuum mechanics, The University of Texas at Austin, v. 1.2.2, 2020.*<br>• *Durran, Dale R. Numerical methods for wave equations in geophysical fluid dynamics. Vol. 32. Springer Science & Business Media, 2013.*<br>• *Moczo, Peter, Jozef Kristek, and Martin Gális. The finite-difference modelling of earthquake motions: Waves and ruptures. Cambridge University Press, 2014. • Trefethen, Lloyd Nicholas. "Finite difference and spectral methods for ordinary and partial differential equations.", 1996.*<br>• *Fletcher, Clive AJ. Computational techniques for fluid dynamics 1: fundamental and general techniques. Springer Science & Business Media, 2005.* |
| **12.** | **Prerequisites:**<br>*Good background in linear algebra and medium level of programming skills in Matlab/Python* |

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| **13.** | **Educational outcomes:** | **PQF level 8 codes:** |
| | ***Knowledge:***<br>*Students will know and understand:*<br>• *To solve ordinary or partial differential equations numerically,*<br>• *The most usable numerical methods and their advantages and limitations,*<br>• *To implement numerical methods with MATLAB/Python* | *P8S_WG* |
| | ***Practical Skills:***<br>*Students will able:*<br>• *To select the best numerical method fit to solve their own ordinary or partial differential equation,*<br>• *To use the programming language MATLAB/Python to solve their ordinary or partial differential equations numerically,*<br>• *Optimize the numerical methods for their specific problems.* | *P8S_UW* |
| | ***Social Skills:***<br>*Students will ready to:*<br>• *Take a key part in the studies that need numerical modeling of physical behavior,* | *P8S_KK* |

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| | • *Evaluate and assess development in the field of numerical methods.* | |
| **14.** | **Evaluation of the educational outcomes:**<br>*- Attendance and activity during classes (20% of the final grade).*<br>*- Short presentation on a selected topic in line with the student's specialization (20% of the final grade)*<br>*- Homework Assignments (40% of the final grade):*<br>*- Final exam (20% of the final grade)* | |
| **15.** | **Criteria to complete the course:**<br>*At least 70% of the final grade* | |
| **16.** | **Contact with the course leader/lecturer:**<br>*Email: tzand@igf.edu.pl* | |