Week 8. Exam scope

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TUDelft

Learning objectives

At the end of this course you will be able to:

- **LO1**: Construct a model that represents an offshore/hydraulic engineering application, limited to models that can be constructed from a combination of: point masses, rigid bodies, rods, Euler-Bernoulli beams, two-dimensional linear elastic objects or geometrically non-linear rods.
- **LO2**: Derive the equations of motion of the model, subject to typical offshore loads such as: wind, waves and currents.
- **LO3**: Define different numerical methods for ODEs and PDEs, including: Finite Differences and Finite Element methods.
- **LO4**: Implement the numerical methods and solve the problem using Matlab, Python or other programming languages.
- **LO5**: Analyse the results by: validating against analytical solutions, identifying the range of applicability of a given method, evaluating errors and assessing the convergence of the solution.

1

Computational methods for ODEs

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Taylor Series

You should be able to:

- explain what the order of a truncated series is
- Perform calculations with orders
- take the TSE of a simple equation

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ODE solver

You should be able to:

- Derive a simple ODE-solver starting from a TSE (limited to Forward Euler)
- Explain what the local & global error of a solver are
- Relate global and local error with convergence rates

Time stepping

You should be able to:

- Identify the differences between a fixed and variable time step
- Explain what relative and absolute tolerances are and why we need them
- Explain how the variable time step is determined based on the relative and absolute tolerances
- Explain how a variable time step affects the performance / behaviour of a solver

ODE Solver types

You should be able to identify if a given scheme is:

- Explicit or implicit
- Single-step or multi-step
- Single-stage or multi-stage

2

Dynamics of rigid bodies

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Structural models

You should be able to

- Create a suitable model of a given real-world scenario (limited to structural elements covered during the course)
- Explain the properties / capabilities / assumptions of the structural models

• Be able to derive EOMs using the Euler-Lagrange approach.

o Limited to setting up the Lagrangian of simple system (you will NOT be asked to derive the equal EOMs once you have the Lagrangian) . Simple system are limited to point masses, rigid bodies, constraints and springs / dampers.

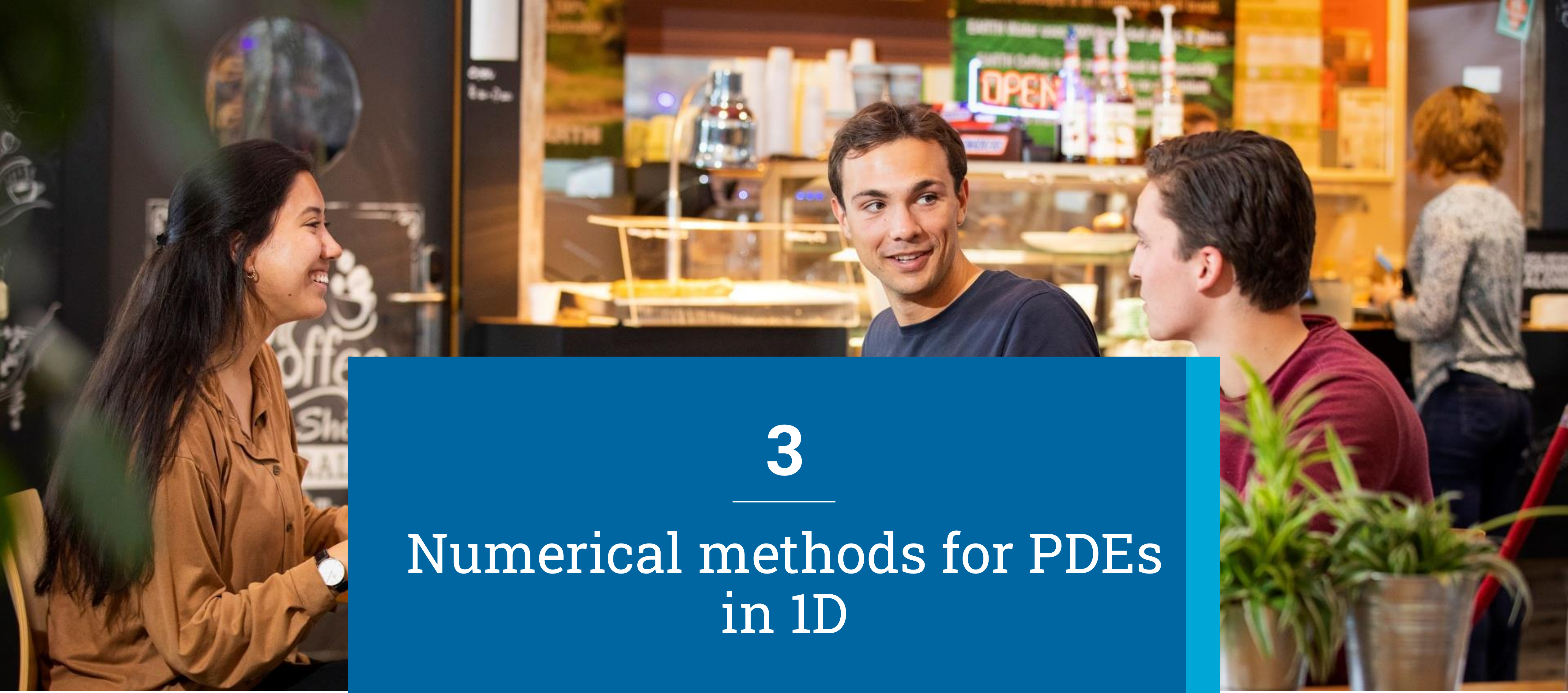
• Be able to analyse and explain the limitations of linearized systems.

o YoumaybeaskedtolinearizetheEOMsofasimplesystem,i.e.knowhowtolinearize cos(), sin().

Lagrangian mechanics

You should be able to

- Derive EOMs using the Euler-Lagrange approach. Limited to setting up the Lagrangian of simple system (you will NOT be asked to derive the equal EOMs once you have the Lagrangian)
- Linearize the resulting EOM
- Analyse and explain the limitations of linearized systems



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Numerical methods for PDEs in 1D

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Finite Differences

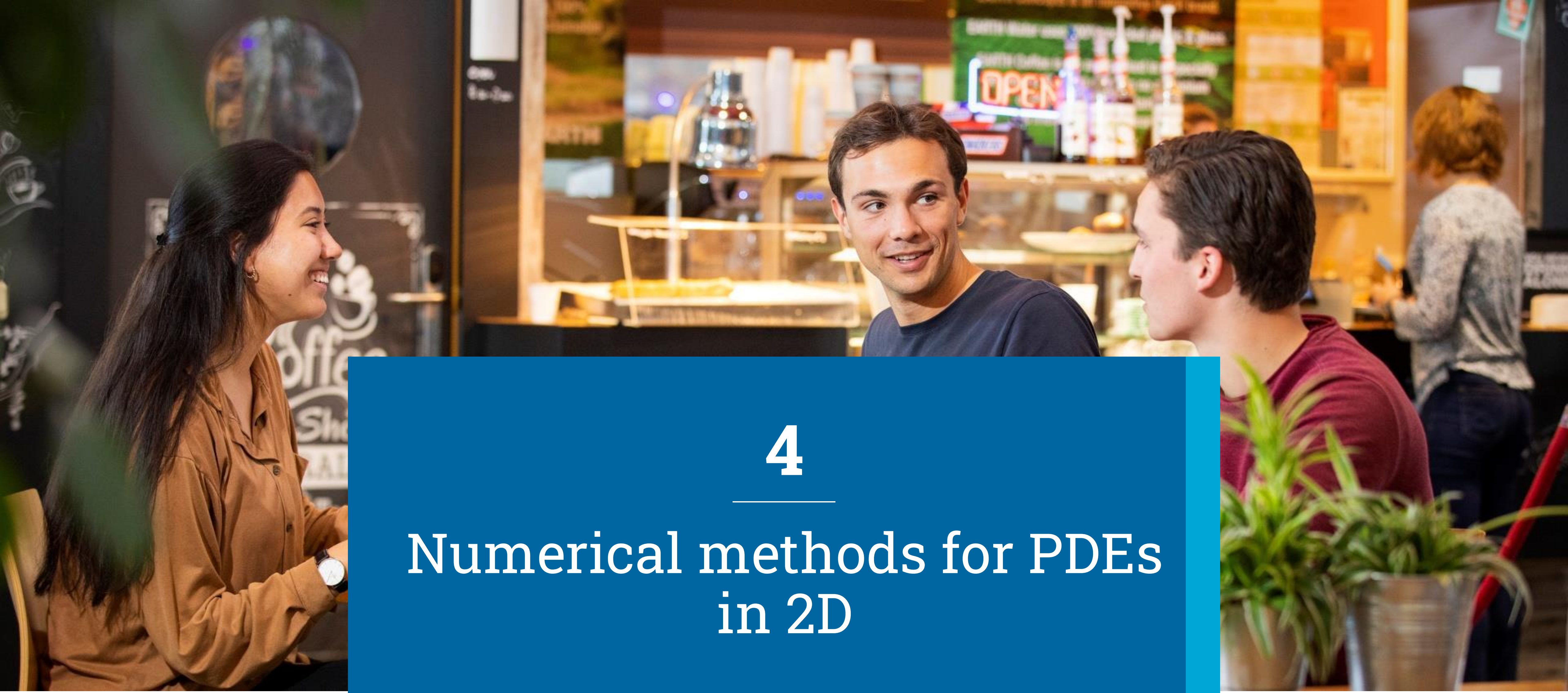
You should be able to

- Discretize a 1-dimensional PDE using FD, including boundary conditions, loads, and to derive the set of matrices.
  - Limited to derivatives of at most 4th order, i.e. w’, w”, w’’’, w””.
  - If asked in the exam, you will be given the tables with FD coefficients

Finite Elements

You should be able to

- Apply the FEM method to obtain the mass and stiffness matrices of a given element type (Euler Beam / String / Rod: the differential equation of the element type will be given)
- Choose interpolation functions suitable for the problem to be solved
- Derive the weak form (also called weighted residual) as function of the nodal values of the degrees of freedom
- Define and use local matrices and rotated matrices
- Assemble the matrices of an element into the global matrices of a structure
- Define what are the free degrees of freedom and fixed degrees of freedom



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Numerical methods for PDEs in 2D

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Finite Elements for static plane strain problems

You should be able to

- Apply the FEM method to obtain the stiffness matrix of a linear elastic 2-dimensional object in plane strain
- Choose interpolation functions suitable for the problem to be solved
- Derive the weak form as function of the nodal values of the degrees of freedom
- Assemble the matrices of an element into the global matrices of a structure
- Define what are the free degrees of freedom and fixed degrees of freedom

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Finite Elements for transient plane strain problems

You should be able to

- Apply the FEM method to obtain the mass and stiffness matrix of a linear elastic 2-dimensional object in plane strain
- Derive the weak form as function of the nodal values of the degrees of freedom
- Assemble the matrices of an element into the global matrices of a structure
- Define what are the free degrees of freedom and fixed degrees of freedom
- Apply time-dependent forces and boundary conditions

5

Modal analysis

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Modal superposition

You should be able to

- Explain the assumptions behind modal superposition
- Explain what may be the advantages of using modal superposition
- Define an appropriate modal basis (for given excitations)
- Identify different damping strategies that preserve the modal orthogonality

6

Geometrically nonlinear structures

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Geometrically nonlinear structures

You should be able to

- Explainthe difference between small and large deformations (what are the assumptions distinguishing them and what are the differences in the solution methods)
- Define reasonable configurations for “initial guess”, depending on the boundary conditions.
- Explain what numerical problems we can face when solving non-linear system of equations, and how they can be addressed.

Thank you for your attention

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