ME-716

Similarity and Transport Phenomena in Fluid

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Cursus	Sem.	Type
Mechanics		Opt.

Language of teaching	English
Credits	2
Session	
Exam	Project report
Workload	60h
Hours	**28**
Courses	20
Exercises	8
Number of positions	**20**

Frequency

Every 2 years

Remark

Next time: Fall 2027

Summary

The course is an introduction to symmetry analysis in fluid mechanics. The student will learn how to find similarity and travelling-wave solutions to partial differential equations used in fluid and continuum mechanics. The course covers mathematical and physical aspects

Content

Chapter 1: The concept of similarity
- Geometrical similarity
- Invariance by affine transformation, rotation, translation
- Fractal similarity
- Scaling law
- Physical similarity
- Complete similarity: drag force
- Incomplete similarity: flow resistance

Chapter 2: Transport phenomena in fluid dynamics
- Transport phenomena
- Advection
- Diffusion Heat equation
- Wave
- Shocks and conservation equations
- Boundary problems: fixed boundary, boundary layer, free boundary problem
- Classification of partial differential equations
- First-order equation, characteristic form
- Second order equation, hyperbolic, elliptic, parabolic

Chapter 3: One-parameter groups, Lie groups
- Groups of transformation
- Group invariants
- Invariant curves
- Transformation of derivative

Chapter 4: First-order differential equations
- Phase portrait
- Singular point
- Separatrix
- Integrating factor
- Invariant integral curves

- Singular solution
- Change of variables

Chapter 5: Second-order differential equations

- Invariant differential equations
- Lie's reduction theorem
- Stretching group
- Singularities

Chapter 6: Similarity solutions to partial differential equation

- Similarity solutions
- Associated stretching group
- Asymptotic behavior
- Determining equations

Chapter 5: Travelling wave solution

- Translation groups
- Example: diffusion with source
- Propagation velocity
- Approach to travelling waves

Chapter 8: Hyperbolic problems

Hyperbolic problems

- One dimensional problems
- Characteristic equations
- Shock formation
- The Riemann problem

Generalization to multidimensional problems

- Linear systems
- Nonlinear systems
- The shallow-water equations

Chapter 9: Parabolic problems

- Linear diffusion
- Nonlinear diffusion
- Stefan problem
- Boundary layer problem

Keywords

partial differential equation, diffusion, advection, similarity solutions, travelling wave solution, hyperbolic problems

Resources

Bibliography

Bibliography is provided on the webpage

Websites

- http://lhe.epfl.ch/doctorate-en.php

Moodle Link

- https://go.epfl.ch/ME-716