# Computational Fluid Dynamics (SG2212/SG3114), 7.5 ECTS

## Lecturers:

**Philipp Schlatter** (PS), *pschlatt@mech.kth.se*, Mekanik, tel 790 7176

Office hours: Friday 14-15

**Ardeshir Hanifi** (AH), *hanifi@kth.se*, Mekanik/FOI, tel 790 8482, 5550 3197

Office hours**:** Monday 14-15

## Assistants:

**Azad Noorani** (AN), *azad@kth.se*, Mekanik, tel 790 8034

Office hours: Wednesday 14-17

**Taras Khapko** (TK), *taras@mech.kth.se*, Mekanik, tel 790 7152

Office hours: Thursday 14-17

## Literature:

Relevant books:

- *Computational Fluid Dynamics*, John D. Anderson, Jr., McGraw-Hill, 1995
- *Numerical Computation of Internal & External Flows*, Charles Hirsch, Butterworth-Heinemann, Second Edition, ISBN: 978-0-7506-6594-0.

*Lecture notes on Computational Fluid Dynamics* (D. Henningson)
*Lecture notes on Basic Numerics (*K. Gustavsson)

## Grading:

Exam total of 50p,

Homework (compulsory) 6×2 + project (compulsory) 5 ⇒ max 15p.

Total points >28 (E), >30 (D), >40 (C), >50 (B), >55 (A).

## Web links:

https://www.kth.se/social/course/SG2212/

## Homeworks: (5 of 6 are compulsory)

- Homework 1, due 21/1
- Homework 2, due 28/1
- Homework 3, due 4/2
- Homework 4, due 11/2
- Homework 5, due 25/2
- Homework 6, due 4/3

## Project (compulsory):

Project, due 18/3

## Course plan

| | | | | | | |
|---|---|---|---|---|---|---|
| Week 3 | Mon | 14 Jan | 13-15 | Q36 | Fluid dynamics I:<br>Introduction and outline of the course.<br>Derivation of the governing equation. | AH |
| | Tue | 15 Jan | 15-17 | Q34 | Fluid dynamics II<br>Derivation of the governing equation , cont. | AH |
| | Thu | 17 Jan | 13-15 | Q34 | Fluid dynamics III:<br>Derivation of the governing equation , cont. | AH |
| Week 4 | Mon | 21 Jan | 13-15 | Q36 | Basic numerics I:<br>Mathematical behavior of hyperbolic, parabolic and elliptic equation. Well-posedness. | PS |
| | Wed | 23 Jan | 15-17 | Q34 | Basic numerics II:<br>Discretization by finite differences. Analysis of discretized equation; order of accuracy, Convergence | PS |
| | Thu | 24 Jan | 15-17 | Q34 | Basic numerics III:<br>Analysis of discretized equation, cont.<br><br>**Homework review:**<br>**Solution of HW1**<br>**Description of HW2** | PS<br><br>TK, AN |
| Week 5 | Mon | 28 Jan | 13-15 | V32 | Analysis of discretized equations: Consistency, Convergence and Stability, CFL condition | PS |
| | Wed | 30 Jan | 10-12 | Q31 | Compressible flow I:<br>Introduction to compressible flow, Euler equation, conservation laws, entropy | PS |
| | Fri | 1 Feb | 13-15 | Q34 | Compressible flow II:<br>Numerical methods for conservation laws, Stability, Dispersion, Diffusion<br><br>**Homework review:**<br>**Solution of HW2**<br>**Description of HW3** | PS<br><br>TK, TM |
| Week 6 | Mon | 4 Feb | 13-15 | V32 | Compressible flow III:<br>Shock tube, boundary conditions, artificial viscosity | PS |
| | Wed | 6 Feb | 10-12 | L52 | Compressible flow IV:<br>Systems of conservation laws, Riemann Invariants | PS |
| | Thu | 7 Feb | 13-15 | V32 | Introduction to incompressible flow. Navier-Stokes in integral form.<br>Finite volume and finite difference methods:<br>Laplace equation on arbitrary grids, equivalence with finite-differences.<br><br>**Homework review:**<br>**Solution of HW3**<br>**Description of HW4** | AH<br><br>TK, AN |

| | | | | | | |
|---|---|---|---|---|---|---|
| Week 7 | Mon | 11 Feb | 13-15 | Q36 | Finite volume and finite difference methods:<br>Cartesian grid and spurious solutions. Staggered grid/volume formulation + BC. | AH |
| | Wed | 13 Feb | 08-10 | V32 | Steady incompressible flows: Artificial compressibility | AH |
| | Fri | 15 Feb | 08-10 | L52 | Projection on divergence-free space,<br>Unsteady incompressible flows: projection method, discrete Poisson pressure eq.<br><br>**Homework review:**<br>**Solution of HW4** | AH<br><br>TK, AN |
| Week 8 | Mon | 18 Feb | 13-15 | Q36 | linear systems: Iterative methods, Gauss-Seidel as smothers for multi-grid | AH |
| | Wed | 20 Feb | 10-12 | V32 | Complex geometries, Coordinate transformation. | AH |
| | Thu | 21 Feb | 15-17 | V34 | Unstructured Node-Centered FV: consistency and accuracy.<br><br>**Homework review:**<br>**Description of HW5** | AH<br><br>TK, AN |
| Week 9 | Tue | 26 Feb | 08-10 | Q36 | Upwind schemes, Flux splitting | AH |
| | Wed | 27 Feb | 08-10 | Q36 | High-order compact finite differences. | AH |
| | Thu | 28 Feb | 15-17 | V34 | **Introduction of project**<br><br>**Homework review:**<br>**Solution of HW5**<br>**Description of HW6** | PS-AH<br><br>TK, AN |
| Week 10 | Mon | 4 Mar | 13-15 | V34 | **Project lecture** | PS |
| | Thu | 7 Mar | 15-17 | V34 | **Project supervision** | TK, AN |
| | Fri | 8 Mar | 10-12 | Q34 | **Homework review:**<br>**Solution of HW6**<br>**Demonstration of project** | TK, AN |
| | Fri | 15 Mar | 14-18 | Q34<br>Q36 | **Examination** | |
| | Thu | 30 May | 09-13 | E51 | **Re-exam** | |