

Guia docent

295455 - 295TM122 - Mecànica de Fluids Computacional

Última modificació: 18/03/2024

Unitat responsable: Escola d'Enginyeria de Barcelona Est
Unitat que imparteix: 729 - MF - Departament de Mecànica de Fluids.

Titulació: MÀSTER UNIVERSITARI EN TECNOLOGIES MECÀNIQUES (Pla 2024). (Assignatura optativa).

Curs: 2024 **Crèdits ECTS:** 6.0 **Idiomes:** Castellà, Anglès

PROFESSORAT

Professorat responsable: Garcia Gonzalez, Fernando
Jofre Cruanyes, Lluís

Altres: Capuano, Francesco

REQUISITS

Tecnologies avançades en ciència i enginyeria de fluids

METODOLOGIES DOCENTS

OBJECTIUS D'APRENENTATGE DE L'ASSIGNATURA

- Aprendre a identificar problemes de mecànica de fluids les solucions dels quals requereixen enfocaments computacionals
- Comprendre els conceptes i idees matemàtiques darrere dels mètodes utilitzats
- Implementar els mètodes corresponents utilitzant llenguatges de programació consolidats
- Realitzar una anàlisi exhaustiva d'errors dels algorismes, inclosa la precisió i l'estabilitat
- Adquirir coneixements sobre la solució discreta i l'optimització d'equacions diferencials que descriuen problemes de fluids en ciència i enginyeria

HORES TOTALES DE DEDICACIÓ DE L'ESTUDIANTAT

Tipus	Hores	Percentatge
Hores aprenentatge autònom	108,0	72.00
Hores grup gran	21,0	14.00
Hores grup petit	21,0	14.00

Dedicació total: 150 h

CONTINGUTS

Mètodes numèrics

Descripció:

Basic remarks. Numerical interpolation and differentiation based on Taylor series expansion. Truncation error: formal definition. Centered and asymmetric derivative formulas. Derivation of finite-difference formulas with arbitrary stencil and order of accuracy on uniform and non-uniform meshes. Matrix notation. Boundary value problems. Numerical solution of 1D and 2D heat equation with Neumann, Dirichlet and Robin boundary conditions. Solution of linear systems: direct and iterative methods. Initial value problems. Ordinary differential equations (ODEs): basic theoretical aspects. Numerical methods for ODEs: multi-stage (Runge-Kutta) and multi-step (Adams) schemes. Partial differential equations (PDEs). Derivation of PDEs relevant to transport phenomena. The semi-discrete (or method of lines) approach. Numerical solution of unsteady advection-diffusion equations using finite-difference formulas and methods for ODEs for a variety of initial and boundary conditions.

Dedicació: 43h 30m

Grup gran/Teoria: 6h

Grup petit/Laboratori: 6h

Activitats dirigides: 1h 30m

Aprenentatge autònom: 30h

Solució numèrica de les equacions de Navier-Stokes

Descripció:

Introduction. General overview of a Computational Fluid Dynamics (CFD) process: mesh generation, solution, post-processing; examples. Basic properties of Navier-Stokes equations. The incompressible flow model. The role of pressure, initial and boundary conditions.

Discretization of incompressible N-S. The pressure Poisson equation and projection methods. Chorin-Temam fractional step method. Layout of variables: collocated and staggered arrangement. The "Harlow-Welch" staggering. Implementation of boundary conditions. Development of a numerical code in primitive variables using a second-order staggered scheme and the projection method. A simple example: the lid-driven cavity problem.

Other topics. Towards multiscale flow problems: the modified wavenumber analysis and the issue of non-linear stability. Remarks on the concept of discrete energy conservation. Remarks on the compressible Navier-Stokes equations and related numerical schemes. Alternatives to projection methods: SIMPLE and PISO algorithms.

Dedicació: 43h 30m

Grup gran/Teoria: 6h

Grup petit/Laboratori: 6h

Activitats dirigides: 1h 30m

Aprenentatge autònom: 30h

Computació d'alt rendiment

Descripció:

Modern processors & data access. Introduction to parallel computing (what, why, how). Parallel computer memory architectures: shared, distributed, hybrid shared-distributed. Fundamentals of parallelization: strong and weak scalability, parallel efficiency, load balance, parallel overheads.

Shared-memory parallel programming (OpenMP). General characteristics. Uniform & Non-Uniform Memory Access (UMA/NUMA). Introduction to OpenMP. Case study: OpenMP-parallel Jacobi algorithm.

Distributed-memory parallel programming (MPI). General characteristics. Messages and point-to-point communication & Nonblocking point-to-point communication. Introduction to MPI. Case study: MPI-parallel Jacobi algorithm.

Hybrid architectures & accelerators (OpenACC). Exascale computing & hybrid architectures. Acceleration strategies. Introduction to OpenACC. Case study: OpenACC-accelerated Jacobi algorithm.

Dedicació: 19h 30m

Grup gran/Teoria: 3h

Grup petit/Laboratori: 3h

Activitats dirigides: 1h 30m

Aprenentatge autònom: 12h

Anàlisi computacional de fluids

Descripció:

Computational experiments. Basic definitions, historical notes and different approaches (theoretical, experimental, computational), application to hydrodynamic instabilities and turbulence.

Analysis of flow regimes. Base flow of a Navier-Stokes problem. Types of bifurcations (Hopf, pitchfork, saddle-node). Linear stability analysis. Overview of numerical techniques. Case study: the two-dimensional lid-driven cavity problem.

Tools for time-dependent flows. Types of time dependent flows (base, quasi-periodic, chaos). Qualitative measures of the flow. Modal flow analysis (POD, DMD). Dynamical indicators from time series (local, global, Poincaré sections). Case study: the two-dimensional lid-driven cavity problem.

Dedicació: 43h 30m

Grup gran/Teoria: 6h

Grup petit/Laboratori: 6h

Activitats dirigides: 1h 30m

Aprenentatge autònom: 30h

SISTEMA DE QUALIFICACIÓ

20% Computational exercises/activities

35% Course project

45% Final exam

BIBLIOGRAFIA

Bàsica:

- LeVeque, Randall J. Finite difference methods for ordinary and partial differential equations : steady-state and time-dependent problems [en línia]. Philadelphia, PA: SIAM, Society for Industrial and Applied Mathematics, 2007 [Consulta: 18/09/2024]. Disponible a: <https://faculty.washington.edu/rjl/fdmbook/>. ISBN 9780898716290.

- Ferziger, Joel H.; Peric, Milovan; Street, Robert L. Computational Methods for Fluid Dynamics. Fourth edition. Cham: Springer, [2019]. ISBN 9783319996912.

- Hager, Georg; Wellein, Gerhard. Introduction to high performance computing for scientists and engineers. Boca Raton, FL: CRC Press, cop. 2011. ISBN 9781439811924.

- Drazin, P. G. Introduction to hydrodynamic stability. Cambridge, UK [etc.]: Cambridge University Press, 2002. ISBN 9780521009652.