Guía docente
295455 - 295TM122 - Mecánica de Fluidos Computacional

Última modificación: 18/03/2024

Unidad responsable: Escuela de Ingeniería de Barcelona Este
Unidad que imparte: 729 - MF - Departamento de Mecánica de Fluidos.

Titulación: MÁSTER UNIVERSITARIO EN TECNOLOGÍAS MECÁNICAS (Plan 2024). (Asignatura optativa).

Curso: 2024 **Créditos ECTS:** 6.0 **Idiomas:** Castellano, Inglés

PROFESORADO

Profesorado responsable: Garcia Gonzalez, Fernando
Jofre Cruanyes, Lluís

Otros: Capuano, Francesco

REQUISITOS

Tecnologías avanzadas en ciencia e ingeniería de fluidos

METODOLOGÍAS DOCENTES

OBJETIVOS DE APRENDIZAJE DE LA ASIGNATURA

- Aprender a identificar problemas de mecánica de fluidos cuyas soluciones requieren enfoques computacionales
- Comprender los conceptos e ideas matemáticas detrás de los métodos utilizados.
- Implementar los métodos correspondientes utilizando lenguajes de programación bien establecidos.
- Realizar un análisis de errores exhaustivo de los algoritmos, incluida la precisión y la estabilidad.
- Adquirir experiencia en la solución discreta y optimización de ecuaciones diferenciales que describen problemas de fluidos en ciencia e ingeniería

HORAS TOTALES DE DEDICACIÓN DEL ESTUDIANTADO

Tipo	Horas	Porcentaje
Horas grupo pequeño	21,0	14.00
Horas grupo grande	21,0	14.00
Horas aprendizaje autónomo	108,0	72.00

Dedicación total: 150 h

CONTENIDOS

Métodos numéricos

Descripción:
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.

Dedicación: 43h 30m
Grupo grande/Teoría: 6h
Grupo pequeño/Laboratorio: 6h
Actividades dirigidas: 1h 30m
Aprendizaje autónomo: 30h

Solución numérica de las ecuaciones de Navier-Stokes

Descripción:
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.

Dedicación: 43h 30m
Grupo grande/Teoría: 6h
Grupo pequeño/Laboratorio: 6h
Actividades dirigidas: 1h 30m
Aprendizaje autónomo: 30h

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Computación de alto rendimiento

Descripción:
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.

Dedicación: 19h 30m
Grupo grande/Teoría: 3h
Grupo pequeño/Laboratorio: 3h
Actividades dirigidas: 1h 30m
Aprendizaje autónomo: 12h

Análisis computacional de fluidos

Descripción:
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.

Dedicación: 43h 30m
Grupo grande/Teoría: 6h
Grupo pequeño/Laboratorio: 6h
Actividades dirigidas: 1h 30m
Aprendizaje autónomo: 30h

SISTEMA DE CALIFICACIÓN

20% Computational exercices/activities
35% Course project
45% Final exam

BIBLIOGRAFÍA

Básica:
- LeVeque, Randall J. Finite difference methods for ordinary and partial differential equations : steady-state and time-dependent problems [en línea]. 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.