UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

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	102,0	68.00
Horas actividades dirigidas	6,0	4.00

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 . Philadelphia, PA : SIAM, Society for Industrial and Applied Mathematics, 2007. ISBN 978-0-89871-629-0.
- Ferziger, Joel H; Peric, Milovan; Street, Robert L. Computational Methods for Fluid Dynamics . Fourth edition. Cham : Springer, [2019]. ISBN 978-3-319-99691-2.
- Hager, G. & Wellein, G.. Introduction to high performance computing for scientists and engineers. Boca Raton, FL, USA: CRC Press, 2011. ISBN 978-1-4398-1192-4.
- Drazin, P. G. Introduction to hydrodynamic stability . Cambridge, UK [etc.] : Cambridge University Press, 2002. ISBN 978-0521009652.